[illegible]

THE SCHOLAR'S LIBRARY
General Editor:—Guy Boas, M.A.

READINGS FROM THE SCIENTISTS
AN ANTHOLOGY

READINGS FROM THE SCIENTISTS

AN ANTHOLOGY

Selected and Edited by

J. EDWARD MASON

M.A., M.ED.

MACMILLAN AND CO., LIMITED

ST. MARTIN'S STREET, LONDON

1937

First Edition 1935
Reprinted 1936, 1937

PRINTED IN GREAT BRITAIN
BY R. & R. CLARK, LIMITED, EDINBURGH

ACKNOWLEDGMENTS

For permission to reprint the copyright material included in this volume the compiler is indebted to the following: The D. Appleton-Century Company, for "Soda Water," from *Chats on Science*, by Edwin E. Slosson; Mr. William Beebe, for "The Alligators of Guiana" and "Research in a Tropical Jungle," from his *Tropical Wild Life*; The Cambridge University Press, for "Man's Place in the Universe," from *The Nature of the Physical World*, by Sir Arthur Eddington, and "The Study of Astronomy," from *The Universe Around Us*, by Sir James Jeans; Messrs. Chatto & Windus, for "The Pageant of Summer" and "Mind under Water," from *The Life of the Fields*, by Richard Jefferies; Mr. J. T. Cunningham, for "Observations on the Eel"; Messrs. Methuen & Co., Ltd., for the extract from *Relativity*, by Albert Einstein; Mr. John Murray, for "A Scientist's Hut in the Antarctic," from Captain Scott's *Personal Journals*; The Oxford University Press, for "Spinning-Tops" and "Boomerangs," from *Mechanics and Some of its Mysteries*, by V. E. Johnson; and Mr. H. G. Wells, for the extract from *The Time Machine*.

INTRODUCTION

"The words of Mercury are harsh after the songs of Apollo."

IT has long been a popular misconception that the scientist can be no artist, that science concerns itself with the nature of actual things and the deductions which can be drawn therefrom, and that art is more concerned with the manner of things than with things themselves. This is setting the material and the spiritual at variance with a vengeance. But from its inception in the early seventeenth century the Royal Society advised its members to pay attention to the style in which they wrote, and in the end to labour after a manner of writing which should be "as near the mathematical plainness" as they could. This exactitude and appropriateness of language form both the science and the art of writing. There is therefore no reason why the scientist should not be an artist in his writing, while artists of more recent date have shown that the man of letters is not infrequently also a scientist.

This supposed antagonism between the arts and the sciences has been as deep-rooted and as misleading as the one-time popular idea that no man of science could be regarded as a man of God. Either the winning of Nature's secrets, it was believed, was to be had only through the hazarding of the scientist's soul, or the revelations which science inevitably brought resulted ultimately in a lack of respect for the Creator who was responsible for the very existence of the scientist's world.

But modern science gives the lie to both these fallacies. A great discoverer, thoroughly conversant with his subject, however abstruse and difficult that subject may be, is often through the exactitude of his training, the clearness of his observation, and the perfect conception of his thought, a model of simple directness in his writing ; while frequently the immensity of his discovery and the resulting increasing realisation of the wonders of creation, cause him to burst into a spontaneous paean of praise and worship.

The present volume illustrates these phases of scientific writing. In an age which daily becomes more scientific, gleanings from the writings of accepted scientists should prove unusually interesting. They will illustrate too how completely the man of science values the exactitude and appropriateness of language, which only careful study and much application can produce ; while the enthusiasm of the writers will often cause even the most unscientific reader to regard the phenomena of nature with increasing wonder and attention.

J. E. M.

lo

CONTENTS

CHEMISTRY

GEOLOGY

NATURAL HISTORY

MECHANICS

EXPLORATION

CONTENTS

ASTRONOMY

PHYSICS

SCIENCE AND ART

FICTION

CHEMISTRY

E

THE CHEMICAL HISTORY OF A CANDLE

I PURPOSE to bring before you, in the course of these lectures, the Chemical History of a Candle. I have taken this subject on a former occasion; and, were it left to my own will, I should prefer to repeat it almost every year—so abundant is the interest that attaches itself to the subject, so wonderful are the varieties of outlet which it offers into the various departments of philosophy. There is not a law under which any part of this universe is governed which does not come into play, and is touched upon in these phenomena. There is no better, there is no more open door by which you can enter into the study of natural philosophy than by considering the physical phenomena of a candle. I trust, therefore, I shall not disappoint you in choosing this for my subject rather than any newer topic, which could not be better, were it even so good.

We will light one or two, and set them at work in the performance of their proper functions. You observe a candle is a very different thing from a lamp. With a lamp you take a little oil, fill your vessel, put in a little moss or some cotton prepared by artificial means, and then light the top of the wick. When the flame runs down the cotton to the oil, it gets extinguished, but it goes on burning in the part above. Now, I have no doubt you will ask, how is it that the oil, which will not burn of itself, gets up to the top of the cotton, where it will burn? We shall presently

examine that; but there is a much more wonderful thing about the burning of a candle than this. You have here a solid substance with no vessel to contain it; and how is it that this solid substance can get up to the place where the flame is? How is it that this solid gets there, it not being a fluid? or, when it is made a fluid, then how is it that it keeps together? This is a wonderful thing about a candle. Notice a candle which has been burning a little while.

Observe that a beautiful cup is formed just under the flame. As the air comes to the candle it moves upward by the force of the current which the heat of the candle produces, and it so cools all the sides of the wax, tallow, or fuel, as to keep the edge much cooler than the part within; the part within melts by the flame that runs down the wick as far as it can go before it is extinguished, but the part on the outside does not melt. If I made a current in one direction, my cup would be lop-sided, and the fluid would consequently run over,—for the same force of gravity which holds worlds together holds this fluid in a horizontal position, and if the cup be not horizontal, of course the fluid will run away in guttering. You see, therefore, that the cup is formed by this beautifully regular ascending current of air playing upon all sides, which keeps the exterior of the candle cool. No fuel would serve for a candle which has not the property of giving this cup, except such fuel as the Irish bogwood, where the material itself is like a sponge, and holds its own fuel. You readily see, therefore, that you would have a bad result if you were to burn those beautiful candles which are irregular, intermittent in their shape, and cannot therefore have that nicely formed edge to the cup which is the great beauty in a candle. I hope you will now see that the perfection of a process—that is, its utility—is the better point of beauty about it.

It is not the best looking thing, but the best acting thing, which is the most advantageous to us. A good-looking candle is a bad burning one. There will be a guttering round about it because of the irregularity of the stream of air and the badness of the cup which is formed thereby. You may see some pretty examples (and I trust you will notice these instances) of the action of the ascending current when you have a little gutter running down the side of a candle, making it thicker there than it is elsewhere. As the candle goes on burning, this keeps its place and forms a little pillar sticking up by the side, because, as it rises higher above the rest of the wax or fuel, the air gets better round it, and it is more cooled and better able to resist the action of the heat at a little distance. Now, the greatest mistakes and faults with regard to candles, as in many other things, often bring with them instruction which we should not receive if they had not occurred. We come here to be philosophers ; and I hope you will always remember that whenever a result happens, especially if it be new, you should say, " What is the cause ? Why does it occur ? " and you will in the course of time find out the reason.

Then the fluid in the cup rises up the wick, by capillary attraction, and into the place of combustion. You know that the candle flame does not run down to the wax or other matter, and melt it all away, but keeps to its own right place. It is fenced off from the fluid below, and does not encroach on the cup at the sides. I cannot imagine a more beautiful example than the condition of adjustment under which a candle makes one part subserve to the other to the very end of its action. A combustible thing like that, burning away gradually, never being intruded upon by the flame, is a very beautiful sight ; especially when you come to learn what a vigorous thing flame is—what power it has of destroying the wax itself when it gets

hold of it, and of disturbing its proper form if it come only too near.

But how does the flame get hold of the fuel? There is a beautiful point about that—*capillary attraction.* "Capillary attraction!" you say—"the attraction of hairs." Well, never mind the name: it was given in old times, before we had a good understanding of what the real power was. It is by what is called capillary attraction that the fuel is conveyed to the part where combustion goes on, and is deposited there, not in a careless way, but very beautifully in the very midst of the centre of action which takes place around it.

Now, the only reason why the candle does not burn all down the side of the wick is, that the melted tallow extinguishes the flame. You know that a candle, if turned upside down, so as to allow the fuel to run upon the wick, will be put out. The reason is, that the flame has not had time to make the fuel hot enough to burn, as it does above, where it is carried in small quantities into the wick, and has all the effect of the heat exercised upon it.

There is another condition which you must learn as regards the candle, without which you would not be able fully to understand the philosophy of it, and that is the vaporous condition of the fuel. In order that you may understand that, let me show you a very pretty but very commonplace experiment. If you blow a candle out cleverly, you will see the vapour rise from it. You have, I know, often smelt the vapour of a blown-out candle—and a very bad smell it is; but if you blow it out cleverly, you will be able to see pretty well the vapour into which this solid matter is transformed. I will blow out one of these candles in such a way as not to disturb the air around it, by the continuing action of my breath; and now, if I hold a lighted taper two or three inches from the wick, you will observe a train of fire going through

the air till it reaches the candle. I am obliged to be quick and ready, because, if I allow the vapour time to cool, it becomes condensed into a liquid or solid, or the stream of combustible matter gets disturbed.

It concerns us much to know about the condition which the matter of the candle finally assumes at the top of the wick—where you have such beauty and brightness as nothing but combustion or flame can produce. You have the glittering beauty of gold and silver, and the still higher lustre of jewels, like the ruby and diamond ; but none of these rival the brilliancy and beauty of flame. What diamond can shine like flame ? It owes its lustre at night-time to the very flame shining upon it. The flame shines in darkness, but the light which the diamond has is as nothing until the flame shines upon it, when it is brilliant again. The candle alone shines by itself, and for itself, or for those who have arranged the materials. Now, let us look a little at the form of the flame as you see it under a glass shade. It is steady and equal ; and its general form varies with atmospheric disturbances, and according to the size of the candle. It is a bright oblong—brighter at the top than towards the bottom—with the wick in the middle, and besides the wick in the middle certain darker parts towards the bottom, where the ignition is not so perfect as in the part above.

And now, I have to ask your attention to the means by which we are enabled to ascertain what happens in any particular part of the flame—why it happens, what it does in happening, and where, after all, the whole candle goes to : because, as you know very well, a candle being brought before us and burned, disappears, if burned properly, without the least trace of dirt in the candlestick—and this is a very curious circumstance. Here is a candle. You see the flame consists of two distinct parts or zones—the central part, which is dark and can be seen at any time if you look

at a candle carefully without blowing it about ; and the outer part of the flame, which is very bright or luminous and readily seen.

We will examine the dark part first.

Now, I take a bent glass tube, and introduce one end into that part of the flame, and you see at once that something is coming from the flame, out at the other end of the tube ; and if I put a flask there, and leave it for a little while, you will see that something from the middle part of the flame is gradually drawn out, and goes through the tube and into that flask, and there behaves very differently from what it does in the open air. It not only escapes from the end of the tube, but falls down to the bottom of the flask like a heavy substance, as indeed it is. We find that this is the wax of the candle made into a vaporous fluid—not a gas. (You must learn the difference between a gas and a vapour : a gas remains permanent, a vapour is something that will condense.) If you blow out a candle, you perceive a very nasty smell, resulting from the condensation of this vapour. That is very different from what you have outside the flame ; and, in order to make that more clear to you, I am about to produce and set fire to a larger portion of this vapour—for what we have in the small way in a candle to understand thoroughly we must, as philosophers, produce in a larger way, if needful, that we may examine the different parts. Here is some wax in a glass flask, and I am going to make it hot, as the inside of that candle-flame is hot, and the matter about the wick is hot. You see that the wax I put in it has become fluid, and there is a little smoke coming from it. We shall very soon have the vapour rising up. I will make it still hotter, and now we get more of it, so that I can actually pour the vapour out of the flask into that basin, and set it on fire there. This, then, is exactly the same kind of vapour as we have in the middle of

the candle; and that you may be sure this is the case, let us try whether we have not got here, in this flask, a real combustible vapour out of the middle of the candle. See how it burns. Now, this is the vapour from the middle of the candle, produced by its own heat; and that is one of the first things you have to consider with respect to the progress of the wax in the course of its combustion, and as regards the changes it undergoes. I will arrange another tube carefully in the flame, and I should not wonder if we were able, by a little care, to get that vapour to pass through the tube to the other extremity, where we will light it, and obtain absolutely the flame of the candle at a place distant from it. Now, look at that. Is not that a very pretty experiment? Talk about laying on gas—why, we can actually lay on a candle! And you see from this that there are clearly two different kinds of action —one the *production* of the vapour, and the other the *combustion* of it—both of which take place in particular parts of the candle.

Very briefly let us examine the outer or luminous part of the candle-flame. If I raise the tube to the upper part of the flame, what comes away will be no longer combustible: it is already burned. How burned? Why, burned thus: In the middle of the flame, where the wick is, there is this combustible vapour; on the outside of the flame is the air which we shall find necessary for the burning of the candle; between the two, intense chemical action takes place, whereby the air and the fuel act upon each other, and at the very same time that we obtain light the vapour inside is destroyed. If you examine where the heat of a candle is, you will find it very curiously arranged. Suppose I hold a piece of paper close upon the flame, where is the heat of that flame? Do you not see that it is *not* in the inside? It is in a ring, exactly in the place where I told you the chemical action was; and

even in my irregular mode of making the experiment, if there is not too much disturbance, there will always be a ring. This is a good experiment for you to make at home. Take a strip of paper, have the air in the room quiet, and put the piece of paper right across the middle of the flame, and you will find that it is burnt in this ring and that it is not burnt, or very little so, in the middle ; and when you have tried the experiment once or twice, so as to make it nicely, you will be very interested to see where the heat is, and to find that it is where the air and the fuel come together.

MICHAEL FARADAY

SODA-WATER

WHEN you are hot and tired from a long walk you naturally drop into the nearest drug-store and take a seat on the wire-legged stool before the marble monument and say to the young man in the apron, " Plain soda, please." Natural enough it is. But funny when you think of it. For what you are paying for is the very thing that you are most anxious to get rid of. What you suck in through the straw is just what you expel with every panting breath.

For soda-water does not contain soda. This is one of these misbrandings that the law allows because it can't stop its use. It is a hang-over word, like " sardines " that never saw Sardinia and " bologna " that does not come from Italy.

Soda-water used to be made from baking-soda by the action of some acid that releases the desired gas. Then limestone was substituted for soda because it was cheaper and just as good. But the thirst of young America seemed likely to melt away mountains of marble, and so it is now customary to catch and compress the gas that escapes from soda-springs or from

the fermenting vats of beer or near-beer or from the combustion of coal.

What soda-water is composed of you may see for yourself if you watch your glass as it stands on the table after you have slaked your first thirst. You will see that it is separating into two different things, a liquid and a gas. 1 The liquid is plain water as you will find out if you are too slow about drinking. The other is a heavy gas that slips up through the water in little bubbles and collects in the empty half of the tumbler. This gas is as invisible as air, but you can prove that it is not air by striking one of the matches on the table before you and plunging it into the upper part of the glass. You will see that the light will be put out before it reaches the water. The gas is so heavy that you can fairly drink it from the glass, and it has, as you know, a tingle-tangle taste. It is also slightly sour, or, as the chemist would call it, a weak acid. "Carbonic acid" is the old name for it, but it is more correct to name it, when it is out of the water, 2 "carbon dioxide."

Into these two things then, water and carbon dioxide, your plain soda dissolves before your eyes. The remarkable thing about it is that all living beings are dissolving into these two things, also before your eyes, though you do not see it.

1 Every plant from the yeast to the pine, every animal from a midge to a man, is continually being converted into water and carbon dioxide and passing off in a gaseous form.

2 While you are musing over it, your glass of soda-water is slowly evaporating. So are you. And into the same elements. You can prove this without leaving your chair. Wipe one side of the tumbler dry with your paper napkin and breathe against the cold glass. There is the dew into which you are dissolving.

The other product of your internal combustion,

carbon dioxide, you can identify if you will ask the clerk in the chemist's shop to pour you out a glass of lime-water. Stick your straw into it but blow instead of sucking. You will see the water turn milky—a common trick of the amateur magician and a proof of the presence of carbon dioxide. This white sediment is the same substance as the original limestone from which the carbon dioxide may have been derived.

You are therefore gradually becoming gasified, and the end-products of your life-reaction are water and carbon dioxide. We may measure your vitality by weighing these products of your activity. If you are leading the sedentary life, your output of soda-water will be low. If you are leading the strenuous life, it will be high.

When you are working hard, say sawing wood or riding a bicycle uphill, you may be exhaling as much as five ounces of carbon dioxide in an hour. When you are sitting still you are exhaling about an ounce.

Food and fuel, the source of animate and inanimate energy, whatever runs our engines or our bodies, all turn out as soda-water in the end. The furnace cannot consume its own smoke in the place of fresh fuel. We must turn over this useless product, soda-water, to the green leaves ; for they, under the stimulus of sunshine, have the power to reverse this reaction, to release the oxygen to the air, and to store up the carbon and hydrogen as food or fuel. In this form they are once more at the disposal of man to furnish him strength to do his work.

So that Yankee ingenuity has converted this waste product of all life into a reinvigorator.

This glass of plain soda is not so plain as it seems at first sight. There is more to be got out of it than the man at the fountain put into it.

Why does the gas escape from the liquid ? Because

the liquid has more gas than it has a legal right to hold. There are two laws regulating this matter. One says that the higher the temperature the less the gas that can be dissolved in a liquid. Your glass of water can hold easily two glassfuls of carbon dioxide when it is ice-cold but only one glassful at the temperature of the room. Since the soda-water as it stands is warming, it must give off half of its gas.

The other law is that the greater the pressure the more gas will be dissolved in a given quantity of water. Under ordinary conditions a pint of water will hold about a pint of gas. Making the pressure four times as great, it will dissolve four pints. The reason why soda-water is so nice is because you get more for your money than you think you are getting. If you pay a nickel for a pint you get five pints of fluid—only a cent a pint. It is consequently very filling and satisfying to the thirsty soul, who, like all human beings, wants so much more than he can hold.

The imprisoned gas, when the pressure is removed by the pulling of a cork or the running from the fountain, tries to escape, and it is very interesting to watch its struggles in your glass. The gas that is dissolved in the water at the surface can go right off into the air, but that which is down deeper has a harder time. The little individual bubbles clinging to the side and bottom are too weak individually to push their way through the water to the top. Then the era of combination begins. Several little bubbles join together and form a syndicate. This draws to it all the little bubbles near it and absorbs them. Some of the bubbles you will see trying to preserve a quasi-independence as they cling together, but the filmy partition finally breaks. The trust is formed and soars upwards, growing as it goes. There are two reasons why it gets bigger as it rises through the water: one is that the pressure gets less, as with a balloon in

the air, and the other is that the gas in the water through which it passes can escape into it as easily as from the surface above.

"Unto him that hath shall be given," is also a physical law. As the bubble gets bigger the pressure holding it in gets weaker, just as when you blow up a circus balloon or one of those inflating squawkers that the children have. You have to blow hard at first, but as the rubber film expands it becomes weaker, and you have to look out or you will burst it with your breath. Now, the bubble of gas in the water is held together by just such an elastic film. You used to call this force "capillary attraction," but you must say "surface tension" or "interfacial energy" nowadays, or else your children will laugh at you.

As the bubbles get bigger, then, the surface tension gets weaker, because it is less arched. It is a poor rule that will not work both ways. All scientific laws should be good rules. Conversely, then, let us say, that the smaller the bubble the greater the force necessary to expand it. That is all right for a way, but if you work it back mathematically to its extreme limit you will reach the absurd conclusion that no bubble can have ever been begun. Or to put it in another way, if the bubble is next to nothing in size it will be next to impossible to start it. The scientists, however, are not at all embarrassed by such a reduction to absurdity. If a law does not go their way they part company with it without a pang. In this case they simply say the rule does not apply to infinitesimal bubbles, which is obviously true.

But you can see for yourself that, even if it is not impossible, it is very difficult for a bubble to get a start in life. The bubbles begin on the sides and bottom of the glass where there is some little irregularity in the surface to give them a chance. If there is a little scratch made by careless scouring of the glass you will

find them lined up along that. A glass with a perfectly smooth, even surface will retain the gas much longer. Champagne glasses have a deep hollow stem from which the bubbles stream up for a long time, so that the liquor will keep " alive " longer. Stir your soda with a straw and see the bubbles rise.

If you don't want the big trust bubbles to rise to the top and escape with their accumulations, thicken the water with some sugar syrup from the other faucet of the fountain, and then the bubbles will accumulate on top in a rosy mass of foam and froth, very pretty, but not good for anything.

But this philosophising makes one thirsty. Our soda-water is getting stale from standing. All the life is going into the foam. Blow it off and drink.

EDWIN E. SLOSSON

GEOLOGY

A PIECE OF CHALK

If a well were sunk at our feet in the midst of the city of Norwich, the diggers would very soon find themselves at work in that white substance almost too soft to be called rock, with which we are all familiar as "chalk."

Not only here, but over the whole county of Norfolk, the well-sinker might carry his shaft down many hundred feet without coming to the end of the chalk; and, on the sea-coast, where the waves have pared away the face of the land which breasts them, the scarped faces of the high cliffs are often wholly formed of the same material. Northward, the chalk may be followed as far as Yorkshire; on the south coast it appears abruptly in the picturesque western bays of Dorset, and breaks into the Needles of the Isle of Wight; while on the shores of Kent it supplies that long line of white cliffs to which England owes her name of Albion.

Were the thin soil which covers it all washed away, a curved band of white chalk, here broader and there narrower, might be followed diagonally across England from Lulworth in Dorset to Flamborough Head in Yorkshire—a distance of over 280 miles as the crow flies. From this band to the North Sea, on the east, and the Channel, on the south, the chalk is largely hidden by other deposits; but, except in the Weald of Kent and Sussex, it enters into the very foundation of all the south-eastern counties.

Attaining, as it does in some places, a thickness of

more than a thousand feet, the English chalk must be admitted to be a mass of considerable magnitude. Nevertheless, it covers but an insignificant portion of the whole area occupied by the chalk formation of the globe, much of which has the same general characters as ours, and is found in detached patches, some less, and others more extensive, than the English.

Chalk occurs in north-west Ireland ; it stretches over a large part of France—the chalk which underlies Paris being, in fact, a continuation of that of the London basin ; it runs through Denmark and Central Europe, and extends southward to North Africa ; while eastward, it appears in the Crimea and in Syria, and may be traced as far as the shores of the Sea of Aral, in Central Asia.

If all the points at which true chalk occurs were circumscribed, they would lie within an irregular oval about 3000 miles in long diameter—the area of which would be as great as that of Europe, and would many times exceed that of the largest existing inland sea—the Mediterranean.

Thus the chalk is no unimportant element in the masonry of the earth's crust, and it impresses a peculiar stamp, varying with the conditions to which it is exposed, on the scenery of the districts in which it occurs. The undulating downs and rounded coombs, covered with sweet-grassed turf, of our inland chalk country, have a peacefully domestic and mutton-suggesting prettiness, but can hardly be called either grand or beautiful. But on our southern coasts, the wall-sided cliffs, many hundred feet high, with vast needles and pinnacles standing out in the sea, sharp and solitary enough to serve as perches for the wary cormorant, confer a wonderful beauty and grandeur upon the chalk headlands. And, in the East, chalk has its share in the formation of some of the most venerable of mountain ranges, such as the Lebanon.

What is this widespread component of the surface of the earth? and whence did it come?

You may think this no very hopeful inquiry. You may not unnaturally suppose that the attempt to solve such problems as these can lead to no result, save that of entangling the inquirer in vague speculations, incapable of refutation and of verification. If such were really the case, I should have selected some other subject than "a piece of chalk" for my discourse. But, in truth, after much deliberation, I have been unable to think of any topic which would so well enable me to lead you to see how solid is the foundation upon which some of the most startling conclusions of physical science rest.

A great chapter of the history of the world is written in the chalk. Few passages in the history of man can be supported by such an overwhelming mass of direct and indirect evidence as that which testifies to the truth of the fragment of the history of the globe which I hope to enable you to read, with your own eyes, to-night.

Let me add that few chapters of human history have a more profound significance for ourselves. I weigh my words well when I assert that the man who should know the true history of the bit of chalk which every carpenter carries about in his breeches-pocket, though ignorant of all other history, is likely, if he will think his knowledge out to its ultimate results, to have a truer, and therefore a better, conception of this wonderful universe, and of man's relation to it, than the most learned student who is deep-read in the records of humanity and ignorant of those of Nature.

The language of the chalk is not hard to learn, not nearly so hard as Latin, if you only want to get at the broad features of the story it has to tell; and I propose that we now set to work to spell that story out together.

We all know that if we " burn " chalk the result is quicklime. Chalk, in fact, is a compound of carbonic acid gas and lime, and when you make it very hot the carbonic acid flies away and the lime is left.

By this method of procedure we see the lime, but we do not see the carbonic acid. If, on the other hand, you were to powder a little chalk and drop it into a good deal of strong vinegar, there would be a great bubbling and fizzing, and, finally, a clear liquid, in which no sign of chalk would appear. Here you see the carbonic acid in the bubbles ; the lime, dissolved in the vinegar, vanishes from sight. There are a great many other ways of showing that chalk is essentially nothing but carbonic acid and quicklime. Chemists enunciate the result of all the experiments which prove this, by stating that chalk is almost wholly composed of " carbonate of lime."

It is desirable for us to start from the knowledge of this fact, though it may not seem to help us very far towards what we seek. For carbonate of lime is a widely-spread substance, and is met with under very various conditions. All sorts of limestones are composed of more or less pure carbonate of lime. The crust which is often deposited by waters which have drained through limestone rocks, in the form of what are called stalagmites and stalactites, is carbonate of lime. Or, to take a more familiar example, the fur on the inside of a tea-kettle is carbonate of lime ; and, for anything chemistry tells us to the contrary, the chalk might be a kind of gigantic fur upon the bottom of the earth-kettle, which is kept pretty hot below.

Let us try another method of making the chalk tell us its own history. To the unassisted eye chalk looks simply like a very loose and open kind of stone. But it is possible to grind a slice of chalk down so thin that you can see through it—until it is thin enough, in fact, to be examined with any magnifying power that may

be thought desirable. A thin slice of the fur of a kettle might be made in the same way. If it were examined microscopically, it would show itself to be a more or less distinctly laminated mineral substance, and nothing more.

But the slice of chalk presents a totally different appearance when placed under the microscope. The general mass of it is made up of very minute granules; but imbedded in this matrix are innumerable bodies, some smaller and some larger, but, on a rough average, not more than a hundredth of an inch in diameter, having a well-defined shape and structure. A cubic inch of some specimens of chalk may contain hundreds of thousands of these bodies, compacted together with incalculable millions of the granules.

The examination of a transparent slice gives a good notion of the manner in which the components of the chalk are arranged, and of their relative proportions. But, by rubbing up some chalk with a brush in water and then pouring off the milky fluid, so as to obtain sediments of different degrees of fineness, the granules and the minute rounded bodies may be pretty well separated from one another, and submitted to microscopic examination, either as opaque or as transparent objects. By combining the views obtained in these various methods, each of the rounded bodies may be proved to be a beautifully constructed calcareous fabric, made up of a number of chambers, communicating freely with one another. The chambered bodies are of various forms. One of the commonest is something like a badly-grown raspberry, being formed of a number of nearly globular chambers of round different sizes congregated together. It is called *Globigerina* and some specimens of chalk consist of little else than *Globigerinae* and granules.

Let us fix our attention upon the *Globigerina*. It is the spoor of the game we are tracking. If we can

learn what it is and what are the conditions of its existence, we shall see our way to the origin and past history of the chalk.

A suggestion which may naturally enough present itself is that these curious bodies are the result of some process of aggregation which has taken place in the carbonate of lime ; that, just as in winter, the rime on our windows simulates the most delicate and elegantly arborescent foliage—proving that the mere mineral, water, may, under certain conditions, assume the outward form of organic bodies—so this mineral substance, carbonate of lime, hidden away in the bowels of the earth, has taken the shape of these chambered bodies. I am not raising a merely fanciful and unreal objection. Very learned men, in former days, have even entertained the notion that all the formed things found in rocks are of this nature ; and if no such conception is at present held to be admissible, it is because long and varied experience has now shown that mineral matter never does assume the form and structure we find in fossils. If any one were to try to persuade you that an oyster-shell (which is also chiefly composed of carbonate of lime) had crystallised out of sea-water, I suppose you would laugh at the absurdity. Your laughter would be justified by the fact that all experience tends to show that oyster-shells are formed by the agency of oysters, and in no other way. And if there were no better reasons, we should be justified, on like grounds, in believing that *Globigerina* is not the product of anything but vital activity.

Happily, however, better evidence in proof of the organic nature of the *Globigerinae* than that of analogy is forthcoming. It so happens that calcareous skeletons, exactly similar to the *Globigerinae* of the chalk, are being formed, at the present moment, by minute living creatures, which flourish in multitudes, literally more numerous than the sands of the seashore, over a

large extent of that part of the earth's surface which is covered by the ocean.

The history of the discovery of these living *Globigerinae*, and of the part which they play in rock building, is singular enough. It is a discovery which, like others of no less scientific importance, has arisen, incidentally, out of work devoted to very different and exceedingly practical interests.

When men first took to the sea, they speedily learned to look out for shoals and rocks ; and the more the burthen of their ships increased, the more imperatively necessary it became for sailors to ascertain with precision the depth of the waters they traversed. Out of this necessity grew the use of the lead and sounding line ; and, ultimately, marine-surveying, which is the recording of the form of coasts and of the depth of the sea, as ascertained by the sounding lead, upon charts.

At the same time, it became desirable to ascertain and to indicate the nature of the sea-bottom, since this circumstance greatly affects its goodness as holding ground for anchors. Some ingenious tar, whose name deserves a better fate than the oblivion into which it has fallen, attained this object by "arming" the bottom of the lead with a lump of grease, to which more or less of the sand or mud, or broken shells, as the case might be, adhered, and was brought to the surface. But, however well adapted such an apparatus might be for rough nautical purposes, scientific accuracy could not be expected from the armed lead, and to remedy its defects (especially when applied to sounding in great depths) Lieut. Brooke, of the American Navy, some years ago invented a most ingenious machine, by which a considerable portion of the superficial layer of the sea-bottom can be scooped out and brought up from any depth to which the lead descends.

In 1853, Lieut. Brooke obtained mud from the bottom of the North Atlantic, between Newfoundland

and the Azores, at a depth of more than 10,000 ft., or two miles, by the help of the sounding apparatus. The specimens were sent for examination to Ehrenberg of Berlin, and to Bailey of West Point, and those able microscopists found that this deep-sea mud was almost entirely composed of the skeletons of living organisms —the greater proportion of these being just like the *Globigerinae* already known to occur in the chalk.

Thus far, the work had been carried on simply in the interests of science, but Lieut. Brooke's method of sounding acquired a high commercial value when the enterprise of laying down the telegraph cable between this country and the United States was undertaken. For it became a matter of immense importance to know, not only the depth of the sea over the whole line along which the cable was to be laid, but the exact nature of the bottom, so as to guard against chances of cutting or fraying the strands of that costly rope. The Admiralty consequently ordered Captain Dayman, an old friend and shipmate of mine, to ascertain the depth over the whole line of the cable, and to bring back specimens of the bottom. In former days, such a command as this might have sounded very much like one of the impossible things which the young prince in the fairy tales is ordered to do before he can obtain the hand of the princess. However, in the months of June and July 1857, my friend performed the task assigned to him with great expedition and precision, without, so far as I know, having met with any reward of that kind. The specimens of Atlantic mud which he procured were sent to me to be examined and reported upon.

The result of all these operations is, that we know the contours and the nature of the surface-soil covered by the North Atlantic for a distance of 1700 miles from east to west, as well as we know that of any part of the dry land.

It is a prodigious plain—one of the widest and most even plains in the world. If the sea were drained off, you might drive a waggon all the way from Valentia, on the west coast of Ireland, to Trinity Bay, in Newfoundland. And, except upon one sharp incline about 200 miles from Valentia, I am not quite sure that it would even be necessary to put the skid on, so gentle are the ascents and descents upon that long route. From Valentia the road would lie downhill for about 200 miles to the point at which the bottom is now covered by 1700 fathoms of sea-water. Then would come the central plain, more than a thousand miles wide, the inequalities of the surface of which would be hardly perceptible, though the depth of water upon it now varies from 10,000 to 15,000 ft. and there are places in which Mont Blanc might be sunk without showing its peak above water. Beyond this, the ascent on the American side commences, and gradually leads, for about 300 miles, to the Newfoundland shore.

Almost the whole of the bottom of this central plain (which extends for many hundred miles in a north and south direction) is covered by a fine mud, which, when brought to the surface, dries into a greyish-white friable substance. You can write with this on a blackboard, if you are so inclined ; and, to the eye, it is quite like very soft, greyish chalk. Examined chemically, it proves to be composed almost wholly of carbonate of lime ; and if you make a section of it, in the same way as that of the piece of chalk was made, and view it with the microscope, it presents innumerable *Globigerinae* embedded in a granular matrix.

Thus this deep-sea mud is substantially chalk. I say substantially, because there are a good many minor differences ; but as these have no bearing on the question immediately before us—which is the

nature of the *Globigerinae* of the chalk—it is unnecessary to speak of them.

Globigerinae of every size, from the smallest to the largest, are associated together in the Atlantic mud, and the chambers of many are filled by a soft animal matter. This soft substance is, in fact, the remains of the creature to which the *Globigerina* shell, or rather skeleton, owes its existence—and which is an animal of the simplest imaginable description. It is, in fact, a mere particle of living jelly, without defined parts of any kind—without a mouth, nerves, muscles, or distinct organs, and only manifesting its vitality to ordinary observation by thrusting out and retracting from all parts of its surface, long filamentous processes, which serve for arms and legs. Yet this amorphous particle, devoid of everything which in the higher animals we call organs, is capable of feeding, growing, and multiplying ; of separating from the ocean the small proportion of carbonate of lime which is dissolved in sea-water ; and of building up that substance into a skeleton for itself, according to a pattern which can be imitated by no other known agency.

The notion that animals can live and flourish in the sea, at the vast depths from which apparently living *Globigerinae* have been brought up, does not agree very well with our usual conceptions respecting the conditions of animal life ; and it is not so absolutely impossible as it might at first sight appear to be that the *Globigerinae* of the Atlantic sea-bottom do not live and die where they are found.

As I have mentioned, the soundings from the great Atlantic plain are almost entirely made up of *Globigerinae*, with the granules which have been mentioned and some few other calcareous shells ; but a small percentage of the chalky mud—perhaps at most some 5 per cent of it—is of a different nature, and con-

sists of shells and skeletons composed of silex, or pure flint. These silicious bodies belong partly to the lowly vegetable organisms which are called *Diatomaceae*, and partly to the minute, and extremely simple, animals, termed *Radiolariae*. It is quite certain that these creatures do not live at the bottom of the ocean, but at its surface—where they may be obtained in prodigious numbers by the use of a properly constructed net. Hence it follows that these siliceous organisms, though they are not heavier than the lightest dust, must have fallen, in some cases, through 15,000 ft. of water, before they reached their final resting-place on the ocean floor. And, considering how large a surface these bodies expose in proportion to their weight, it is probable that they occupy a great length of time in making their burial journey from the surface of the Atlantic to the bottom.

But if the *Radiolariae* and Diatoms are thus rained upon the bottom of the sea from the superficial layer of its waters in which they pass their lives, it is obviously possible that the *Globigerinae* may be similarly derived ; and if they were so, it would be much more easy to understand how they obtain their supply of food than it is at present. Nevertheless, the positive and negative evidence all points the other way. The skeletons of the full-grown, deep-sea *Globigerinae* are so remarkably solid and heavy in proportion to their surface as to seem little fitted for floating ; and, as a matter of fact, they are not to be found along with the Diatoms and *Radiolariae* in the uppermost stratum of the open ocean.

It has been observed, again, that the abundance of *Globigerinae*, in proportion to other organisms, of like kind, increases with the depth of the sea ; and that deep-water *Globigerinae* are larger than those which live in shallower parts of the sea ; and such facts negative the supposition that these organisms

have been swept by currents from the shallows into the deeps of the Atlantic.

It therefore seems to be hardly doubtful that these wonderful creatures live and die at the depths in which they are found.

However, the important points for us are that the living *Globigerinae* are exclusively marine animals, the skeletons of which abound at the bottom of deep seas; and that there is not a shadow of reason for believing that the habits of the *Globigerinae* of the chalk differed from those of the existing species. But if this be true, there is no escaping the conclusion that the chalk itself is the dried mud of an ancient deep sea.

When we consider that the remains of more than 3000 distinct species of aquatic animals have been discovered among the fossils of the chalk, that the great majority of them are of such forms as are now met with only in the sea, and that there is no reason to believe that any one of them inhabited fresh water —the collateral evidence that the chalk represents an ancient sea-bottom acquires as great force as the proof derived from the nature of the chalk itself. I think you will now allow that I did not overstate my case when I asserted that we have as strong grounds for believing that all the vast area of dry land, at present occupied by the chalk, was once at the bottom of the sea, as we have for any matter of history whatever; while there is no justification for any other belief.

No less certain it is that the time during which the countries we now call south-east England, France, Germany, Poland, Russia, Egypt, Arabia, Syria, were more or less completely covered by a deep sea, was of considerable duration.

We have already seen that the chalk is, in places, more than a thousand feet thick. I think you will agree with me that it must have taken some time for the skeletons of animalculae of a hundredth of an

inch in diameter to heap up such a mass as that. I have said that throughout the thickness of the chalk the remains of other animals are scattered. These remains are often in the most exquisite state of preservation. The valves of the shellfishes are commonly adherent ; the long spines of some of the sea-urchins, which would be detached by the smallest jar, often remain in their places. In a word, it is certain that these animals have lived and died when the place which they now occupy was the surface of as much of the chalk as had then been deposited ; and that each has been covered up by the layer of *Globigerina* mud, upon which the creatures imbedded a little higher up have, in like manner, lived and died. But some of these remains prove the existence of reptiles of vast size in the chalk sea. These lived their time, and had their ancestors and descendants, which assuredly implies time, reptiles being of slow growth.

There is more curious evidence, again, that the process of covering up, or in other words, the deposit of *Globigerina* skeletons, did not go on very fast. It is demonstrable that an animal of the cretaceous sea might die, that its skeleton might lie uncovered upon the sea-bottom long enough to lose all its outward coverings and appendages by putrefaction ; and that, after this had happened, another animal might attach itself to the dead and naked skeleton, might grow to maturity, and might itself die before the calcareous mud had buried the whole.

Cases of this kind are admirably described by Sir Charles Lyell. He speaks of the frequency with which geologists find in the chalk a fossilised sea-urchin, to which is attached the lower valve of a *Crania*. This is a kind of shellfish, with a shell composed of two pieces, of which, as in the oyster, one is fixed and the other free.

"The upper valve is almost invariably wanting, though occasionally found in a perfect state of preservation in the white chalk at some distance. In this case, we see clearly that the sea-urchin first lived from youth to age, then died and lost its spines, which were carried away. Then the young *Crania* adhered to the bared shell, grew and perished in its turn; after which, the upper valve was separated from the lower, before the Echinus became enveloped in chalky mud."

Thus, not only is it certain that the chalk is the mud of an ancient sea-bottom; but it is no less certain that the chalk sea existed during an extremely long period, though we may not be prepared to give a precise estimate of the length of that period in years. The relative duration is clear, though the absolute duration may not be definable. The attempt to affix any precise date to the period at which the chalk sea began, or ended, its existence, is baffled by difficulties of the same kind. But the relative age of the cretaceous epoch may be determined with as great ease and certainty as the long duration of that epoch.

You will have heard of the interesting discoveries recently made, in various parts of Western Europe, of flint implements, obviously worked into shape by human hands, under circumstances which show conclusively that man is a very ancient denizen of these regions.

It has been proved that the whole populations of Europe, whose existence has been revealed to us in this way, consisted of savages, such as the Esquimaux are now; that, in the country which is now France, they hunted the reindeer, and were familiar with the ways of the mammoth and the bison. The physical geography of France was in those days different from what it is now—the river Somme, for instance, having cut its bed a hundred feet deeper between that time

and this; and it is probable that the climate was more like that of Canada or Siberia than that of Western Europe.

The existence of these people is forgotten even in the traditions of the oldest historical nations. The name and fame of them had utterly vanished until a few years back; and the amount of physical change which has been effected since their day renders it more than probable that, venerable as are some of the historical nations, the workers of the chipped flints of Hoxne or of Amiens are to them, as they are to us, in point of antiquity.

But, if we assign to these hoar relics of long-vanished generations of men the greatest age that can possibly be claimed for them, they are not older than the drift, or boulder clay, which, in comparison with the chalk, is but a very juvenile deposit. You need go no further than your own seaboard for evidence of this fact. At one of the most charming spots on the coast of Norfolk, Cromer, you will see the boulder clay forming a vast mass, which lies upon the chalk, and must consequently have come into existence after it. Huge boulders of chalk are, in fact, included in the clay, and have evidently been brought to the position they now occupy by the same agency as that which has planted blocks of syenite from Norway side by side with them.

The chalk, then, is certainly older than the boulder clay. If you ask how much, I will again take you no further than the same spot upon your own coasts for evidence. I have spoken of the boulder clay and drift as resting upon the chalk. That is not strictly true. Interposed between the chalk and the drift is a comparatively insignificant layer, containing vegetable matter. But the layer tells a wonderful history. It is full of stumps of trees standing as they grew. Fir trees are there with their cones, and hazel-bushes with their nuts; there stand the stools of oak and yew trees,

beeches and alders. Hence this stratum is appropriately called the "forest-bed."

It is obvious that the chalk must have been upheaved and converted into dry land, before the timber trees could grow upon it. As the boles of some of these trees are from two to three feet in diameter, it is no less clear that the dry land thus formed remained in the same conditions for long ages. And not only do the remains of stately oaks and well-grown firs testify to the duration of this condition of things, but additional evidence to the same effect is afforded by the abundant remains of elephants, rhinoceroses, hippopotamuses, and other great wild beasts, which it has yielded to the zealous search of such men as the Rev. Mr. Gunn.

When you look at such a collection as he has formed, and bethink you that these elephantine bones did veritably carry their owners about, and these great grinders crunch, in the dark woods of which the forest-bed is now the only trace, it is impossible not to feel that they are as good evidence of the lapse of time as the annual rings of the tree stumps.

Thus there is a writing upon the wall of cliffs at Cromer, and whoso runs may read it. It tells us, with an authority which cannot be impeached, that the ancient sea-bed of the chalk sea was raised up, and remained dry land, until it was covered with forest, stocked with the great game the spoils of which have rejoiced your geologists. How long it remained in that condition cannot be said ; but "the whirligig of time brought its revenges" in those days as in these. That dry land, with the bones and teeth of generations of long-lived elephants, hidden away among the gnarled roots and dry leaves of its ancient trees, sank gradually to the bottom of the icy sea, which covered it with huge masses of drift and boulder clay. Sea-beasts, such as the walrus, now restricted to the extreme north, paddled about where birds had twittered among

the topmost twigs of the fir trees. How long this state of things endured we know not, but at length it came to an end. The upheaved glacial mud hardened into the soil of modern Norfolk. Forests grew once more, the wolf and the beaver replaced the reindeer and the elephant ; and at length what we call the history of England dawned.

Thus you have, within the limits of your own country, proof that the chalk can justly claim a very much greater antiquity than even the oldest physical traces of mankind.

Thus evidence which cannot be rebutted, and which need not be strengthened, though if time permitted I might indefinitely increase its quantity, compels you to believe that the earth, from the time of the chalk to the present day, has been the theatre of a series of changes as vast in their amount, as they were slow in their progress. The area on which we stand has been first sea and then land, for at least four alternations ; and has remained in each of these conditions for a period of great length.

Nor have these wonderful metamorphoses of sea into land, and of land into sea, been confined to one corner of England. During the chalk period, or "cretaceous epoch," not one of the present great physical features of the globe was in existence. Our great mountain ranges, Pyrenees, Alps, Himalayas, Andes, have all been upheaved since the chalk was deposited, and the cretaceous sea flowed over the sites of Sinai and Ararat.

All this is certain, because rocks of cretaceous or still later date have shared in the elevatory movements which gave rise to these mountain chains, and may be found perched up, in some cases, many thousand feet high upon their flanks. And evidence of equal cogency demonstrates that, though, in Norfolk, the forest-bed rests directly upon the chalk, yet it does so,

not because the period at which the forest grew immediately followed that at which the chalk was formed, but because an immense lapse of time, represented elsewhere by thousands of feet of rock, is not indicated at Cromer.

I must ask you to believe that there is no less conclusive proof that a still more prolonged succession of similar changes occurred, before the chalk was deposited. Nor have we any reason to think that the first term in the series of these changes is known. The oldest sea-beds preserved to us are sands, and mud, and pebbles, the wear and tear of rocks which were formed in still older oceans.

But, great as is the magnitude of these physical changes of the world, they have been accompanied by a no less striking series of modifications in its living inhabitants.

All the great classes of animals, beasts of the field, fowls of the air, creeping things, and things which dwell in the waters, flourished upon the globe long ages before the chalk was deposited. Very few, however, if any, of these ancient forms of animal life were identical with those which now live. Certainly, not one of the higher animals was of the same species as any of those now in existence. The beasts of the field, in the days before the chalk, were not our beasts of the field, nor the fowls of the air such as those which the eye of man has seen flying, unless his antiquity dates infinitely further back than we at present surmise. If we could be carried back into those times, we should be as one suddenly set down in Australia before it was colonised. We should see mammals, birds, reptiles, fishes, insects, snails, and the like, clearly recognisable as such, and yet not one of them would be just the same as those with which we are familiar, and many would be extremely different.

From that time to the present, the population of the world has undergone slow and gradual, but incessant,

changes. There has been no grand catastrophe—no destroyer has swept away the forms of life of one period, and replaced them by a totally new creation: but one species has vanished and another has taken its place; creatures of one type of structure have diminished, those of another have increased, as time has passed on. And thus, while the differences between the living creatures of the time before the chalk and those of the present day appear startling, if placed side by side, we are led from one to the other by the most gradual progress, if we follow the course of Nature through the whole series of those relics of her operations which she has left behind.

And it is by the population of the chalk sea that the ancient and the modern inhabitants of the world are most completely connected. The groups which are dying out flourish, side by side, with the groups which are now the dominant forms of life.

Thus the chalk contains remains of those strange flying and swimming reptiles, the pterodactyl, the ichthyosaurus, and the plesiosaurus, which are found in no later deposits, but abounded in preceding ages. The chambered shells called ammonites and belemnites, which are so characteristic of the period preceding the cretaceous, in like manner die with it.

But amongst these fading remainders of a previous state of things are some very modern forms of life, looking like Yankee pedlars among a tribe of Red Indians. Crocodiles of modern type appear; bony fishes, many of them very similar to existing species, almost supplant the forms of fish which predominate in more ancient seas; and many kinds of living shellfish first become known to us in the chalk. The vegetation acquires a modern aspect. A few living animals are not even distinguishable as species from those which existed at that remote epoch. The *Globigerina* of the present day, for example, is not different specific-

ally from that of the chalk ; and the same may be said of many other *Foraminiferae*. I think it probable that critical and unprejudiced examination will show that more than one species of much higher animals have had a similar longevity ; but the only example which I can at present give confidently is the snake's-head lamp-shell (*Terebratulina caput serpentis*), which lives in our English seas and abounded in the chalk.

The longest line of human ancestry must hide its diminished head before the pedigree of this insignificant shellfish. We Englishmen are proud to have an ancestor who was present at the Battle of Hastings. The ancestors of *Terebratulina caput serpentis* may have been present at a battle of *Ichthyosauriae* in that part of the sea which, when the chalk was forming, flowed over the site of Hastings. While all around has changed, this *Terebratulina* has peacefully propagated its species from generation to generation, and stands to this day as a living testimony to the continuity of the present with the past history of the globe.

A small beginning has led us to a great ending. If I were to put the bit of chalk with which we started into the hot but obscure flame of burning hydrogen, it would presently shine like the sun. It seems to me that this physical metamorphosis is no false image of what has been the result of our subjecting it to a jet of fervent, though nowise brilliant, thought to-night. It has become luminous, and its clear rays, penetrating the abyss of the remote past, have brought within our ken some stages of the evolution of the earth. And in the shifting " without haste, but without rest " of the land and sea, as in the endless variation of the forms assumed by living beings, we have observed nothing but the natural product of the forces originally possessed by the substance of the universe.

T. H. Huxley

OLD RED SANDSTONE

It was twenty years last February since I set out, a little before sunrise, to make my first acquaintance with a life of labour and restraint ; and I have rarely had a heavier heart than on that morning. I was but a slim, loose-jointed boy at the time, fond of the pretty intangibilities of romance, and of dreaming when broad awake ; and, woeful change ! I was now going to work at what Burns has instanced, in his "Twa Dogs," as one of the most disagreeable of all employments—to work in a quarry. Bating the passing uneasiness occasioned by a few gloomy anticipations, the portion of my life which had already gone by had been happy beyond the common lot. I had been a wanderer among rocks and woods, a reader of curious books when I could get them, a gleaner of old traditionary stories ; and now I was going to exchange all my day-dreams, and all my amusements, for the kind of life in which men toil every day that they may be enabled to eat, and eat every day that they may be enabled to toil !

The quarry in which I wrought lay on the southern shore of a noble inland bay, or frith rather, with a little clear stream on the one side, and a thick fir wood on the other. It had been opened in the Old Red Sandstone of the district, and was overtopped by a huge bank of diluvial clay, which rose over it in some places to the height of nearly thirty feet, and which at this time was rent and shivered, wherever it presented an open front to the weather, by a recent frost. A heap of loose fragments, which had fallen from above, blocked up the face of the quarry, and my first employment was to clear them away. The friction of the shovel soon blistered my hands, but the pain

was by no means very severe, and I wrought hard and willingly, that I might see how the huge strata below, which presented so firm and unbroken a frontage, were to be torn up and removed. Picks, and wedges, and levers, were applied by my brother-workmen ; and, simple and rude as I had been accustomed to regard these implements, I found I had much to learn in the way of using them. They all proved inefficient, however, and the workmen had to bore into one of the inferior strata, and employ gunpowder. The process was new to me, and I deemed it a highly amusing one : it had the merit, too, of being attended with some such degree of danger as a boating or rock excursion, and had thus an interest independent of its novelty. We had a few capital shots : the fragments flew in every direction ; and an immense mass of the diluvium came toppling down, bearing with it two dead birds that in a recent storm had crept into one of the deeper fissures, to die in the shelter. I felt a new interest in examining them. The one was a pretty cock goldfinch, with its hood of vermilion, and its wings inlaid with the gold to which it owes its name, as unsoiled and smooth as if it had been preserved for a museum. The other, a somewhat rarer bird, of the woodpecker tribe, was variegated with light blue and a greyish yellow. I was engaged in admiring the poor little things, more disposed to be sentimental, perhaps, than if I had been ten years older, and thinking of the contrast between the warmth and jollity of their green summer haunts, and the cold and darkness of their last retreat, when I heard our employer bidding the workmen lay by their tools. I looked up and saw the sun sinking behind the thick fir wood beside us, and the long dark shadows of the trees stretching downwards towards the shore.

This was no very formidable beginning of the course of life I had so much dreaded. To be sure, my hands

were a little sore, and I felt nearly as much fatigued as if I had been climbing among the rocks ; but I had wrought and been useful, and had yet enjoyed the day fully as much as usual. It was no small matter, too, that the evening, converted, by a rare transmutation, into the delicious " blink of rest " which Burns so truthfully describes, was all my own. I was as light of heart next morning as any of my brother-workmen. There had been a smart frost during the night, and the rime lay white on the grass as we passed onwards through the fields ; but the sun rose in a clear atmosphere, and the day mellowed, as it advanced, into one of those delightful days of early spring which give so pleasing an earnest of whatever is mild and genial in the better half of the year. All the workmen rested at mid-day, and I went to enjoy my half-hour alone on a mossy knoll in the neighbouring wood, which commands through the trees a wide prospect of the bay and the opposite shore. There was not a wrinkle on the water, not a cloud in the sky, and the branches were as moveless in the calm as if they had been traced on canvas. From a wooded promontory that stretched half-way across the frith there ascended a thin column of smoke. It rose straight as the line of a plummet for more than a thousand yards, and then, on reaching a thinner stratum of air, spread out equally on every side, like the foliage of a stately tree. Ben Wyvis rose to the west, white with the yet unwasted snows of winter, and as sharply defined in the clear atmosphere as if all its sunny slopes and blue retiring hollows had been chiselled in marble. A line of snow ran along the opposite hills : all above was white, and all below was purple. They reminded me of the pretty French story, in which an old artist is described as tasking the ingenuity of his future son-in-law, by giving him as a subject for his pencil a flower-piece composed of only white flowers, of which the one-half were to bear their

proper colour, the other half a deep purple hue, and yet all be perfectly natural ; and how the young man resolved the riddle and gained his mistress, by introducing a transparent purple vase into the picture, and making the light pass through it on the flowers that were drooping over the edge. I returned to the quarry, convinced that a very exquisite pleasure may be a very cheap one, and that the busiest employments may afford leisure enough to enjoy it.

The gunpowder had loosened a large mass in one of the inferior strata, and our first employment, on resuming our labours, was to raise it from its bed. I assisted the other workmen in placing it on edge, and was much struck by the appearance of the platform on which it had rested. The entire surface was ridged and furrowed like a bank of sand that had been left by the tide an hour before. I could trace every bend and curvature, every cross hollow and counter ridge, of the corresponding phenomena ; for the resemblance was no half resemblance—it was the thing itself ; and I had observed it a hundred and a hundred times, when sailing my little schooner in the shallows left by the ebb. But what had become of the waves that had thus fretted the solid rock, or of what element had they been composed? I felt as completely at fault as Robinson Crusoe did on his discovering the print of the man's foot in the sand. The evening furnished me with still further cause of wonder. We raised another block in a different part of the quarry, and found that the area of a circular depression in the stratum below was broken and flawed in every direction, as if it had been the bottom of a pool recently dried up, which had shrunk and split in the hardening. Several large stones came rolling down from the diluvium in the course of the afternoon. They were of different qualities from the sandstone below, and from one another ; and, what was more wonderful still, they

were all rounded and water-worn, as if they had been tossed about in the sea or the bed of the river for hundreds of years. There could not, surely, be a more conclusive proof that the bank which had enclosed them so long could not have been created on the rock on which it rested. No workman ever manufactures a half-worn article, and the stones were all half-worn ! And if not the bank, why then the sandstone underneath ? I was lost in conjecture, and found I had food enough for thought that evening, without once thinking of the unhappiness of a life of labour.

The immense masses of diluvium which we had to clear away rendered the working of the quarry laborious and expensive, and all the party quitted it in a few days, to make trial of another that seemed to promise better. The one we left is situated, as I have said, on the southern shore of an inland bay—the Bay of Cromarty ; the one to which we removed has been opened in a lofty wall of cliffs that overhangs the northern shore of the Moray Frith. I soon found I was to be no loser by the change. Not the united labours of a thousand men for more than a thousand years could have furnished a better section of the geology of the district than this range of cliffs. It may be regarded as a sort of chance dissection on the earth's crust. We see in one place the *primary* rock, with its veins of granite and quartz, its dizzy precipices of gneiss, and its huge masses of horn-blende ; we find the secondary rock in another, with its beds of sandstone and shale, its spars, its clays, and its nodular limestones. We discover the still little-known but highly interesting fossils of the Old Red Sandstone in one deposition, we find the beautifully preserved shells and lignites of the Lias in another. There are the remains of two several creations at once before us. The shore, too, is heaped with rolled fragments of almost every variety of rock—basalts, ironstones,

hyperstenes, porphyries, bituminous shales, and micaceous schists. In short, the young geologist, had he all Europe before him, could hardly choose for himself a better field. I had, however, no one to tell me so at the time, for Geology had not yet travelled so far north ; and so, without guide or vocabulary, I had to grope my way as I best might, and find out all its wonders for myself. But so slow was the process, and so much was I a seeker in the dark, that the facts contained in these few sentences were the patient gatherings of years.

Small lump

In the course of the first day's employment I picked up a nodular mass of blue limestone, and laid it open by a stroke of the hammer. Wonderful to relate, it contained inside a beautifully finished piece of sculpture—one of the volutes, apparently, of an Ionic capital ; and not the far-famed walnut of the fairy tale, had I broken the shell and found the little dog lying within, could have surprised me more. Was there another such curiosity in the whole world ? I broke open a few other nodules of similar appearance—for they lay pretty thickly on the shore—and found that there might. In one of these there were what seemed to be the scales of fishes, and the impressions of a few minute bivalves, prettily striated ; in the centre of another there was actually a piece of decayed wood. Of all Nature's riddles, these seemed to me to be at once the most interesting and the most difficult to expound. I treasured them carefully up, and was told by one of the workmen to whom I showed them that there was a part of the shore about two miles farther to the west where curiously-shaped stones, somewhat like the heads of boarding-pikes, were occasionally picked up ; and that in his father's days the country people called them thunderbolts, and deemed them of sovereign efficacy in curing bewitched cattle. Our employer,

on quitting the quarry for the building on which we were to be engaged, gave all the workmen a half-holiday. I employed it in visiting the place where the thunderbolts had fallen so thickly, and found it a richer scene of wonder than I could have fancied in even my dreams.

What first attracted my notice was a detached group of low-lying skerries, wholly different in form and colour from the sandstone cliffs above or the primary rocks a little farther to the west. I found them composed of thin strata of limestone, alternating with thicker beds of a black slaty substance, which, as I ascertained in the course of the evening, burns with a powerful flame, and emits a strong bituminous odour. The layers into which the beds readily separate are hardly an eighth part of an inch in thickness, and yet on every layer there are the impressions of thousands and tens of thousands of the various fossils peculiar to the Lias. We may turn over these wonderful leaves one after one, like the leaves of a herbarium, and find the pictorial records of a former creation in every page: scallops, and gryphites, and ammonites, of almost every variety peculiar to the formation, and at least some eight or ten varieties of belemnite; twigs of wood, leaves of plants, cones of an extinct species of pine, bits of charcoal, and the scales of fishes; and, as if to render their pictorial appearance more striking, though the leaves of this interesting volume are of a deep black, most of the impressions are of a chalky whiteness. I was lost in admiration and astonishment, and found my very imagination paralysed by an assemblage of wonders that seemed to outrival in the fantastic and the extravagant even its wildest conceptions. I passed on from ledge to ledge, like the traveller of the tale through the city of statues, and at length found one of the supposed aerolites I had come in quest of firmly

imbedded in a mass of shale. But I had skill enough to determine that it was other than what it had been deemed. A very near relative, who had been a sailor in his time on almost every ocean, and had visited almost every quarter of the globe, had brought home one of these meteoric stones with him from the coast of Java. It was of a cylindrical shape and vitreous texture, and it seemed to have parted in the middle when in a half-molten state, and to have united again, somewhat awry, ere it had cooled enough to have lost the adhesive quality. But there was nothing organic in its structure ; whereas the stone I had now found was organised very curiously indeed. It was of a conical form and filamentary texture, the filaments radiating in straight lines from the centre to the circumference. Finely-marked veins like white threads ran transversely through these in its upper half to the point ; while the space below was occupied by an internal cone, formed of plates that lay parallel to the base, and which, like watch-glasses, were concave on the under side and convex on the upper. I learned in time to call this stone a belemnite, and became acquainted with enough of its history to know that it once formed part of a variety of cuttle-fish, long since extinct.

My first year of labour came to a close, and I found that the amount of my happiness had not been less than in the last of my boyhood. My knowledge, too, had increased in more than the ratio of former seasons ; and as I had acquired the skill of at least the common mechanic, I had fitted myself for independence. The additional experience of twenty years has not shown me that there is any necessary connection between a life of toil and a life of wretchedness ; and when I have found good men anticipating a better and a happier time than either the present or the past, the conviction that in every period of

the world's history the great bulk of mankind must pass their days in labour has not in the least inclined me to scepticism.

HUGH MILLER

CORAL FORMATIONS

April 1, 1836.—We arrived in view of the Keeling or Cocos Islands, situated in the Indian Ocean, and about six hundred miles distant from the coast of Sumatra. This is one of the lagoon islands (or atolls) of coral formation, similar to those in the Low Archipelago which we passed near.

The ring-formed reef of the lagoon-island is surmounted in the greater part of its length by linear islets. On the northern or leeward side, there is an opening through which vessels can pass to the anchorage within. On entering, the scene was very curious and rather pretty ; its beauty, however, entirely depended on the brilliancy of the surrounding colours. The shallow, clear, and still water of the lagoon, resting in its greater part on white sand, is, when illumined by a vertical sun, of the most vivid green. This brilliant expanse, several miles in width, is on all sides divided, either by a line of snow-white breakers from the dark heaving waters of the ocean, or from the blue vault of heaven by the strips of land, crowned by the level tops of the cocoa-nut trees. As a white cloud here and there affords a pleasing contrast with the azure sky, so, in the lagoon, bands of living coral darken the emerald-green water.

The next morning, after anchoring, I went on shore on Direction Island. The strip of dry land is only a few hundred yards in width : on the lagoon side there is a white calcareous beach, the radiation from which under this sultry climate was very oppressive ; and on

very hot

the outer coast, a solid broad flat of coral-rock served to break the violence of the open sea. Excepting near the lagoon, where there is some sand, the land is entirely composed of rounded fragments of coral. In such a loose, dry, stony soil, the climate of the intertropical regions alone could produce a vigorous vegetation. On some of the smaller islets, nothing could be more elegant than the manner in which the young and full-grown cocoa-nut trees, without destroying each other's symmetry, were mingled into one wood. A beach of glittering white sand formed a border to these fairy spots.

The long strips of land, forming the linear islets, have been raised only to that height to which the surf can throw fragments of coral and the wind heap up calcareous sand. The solid flat of coral rock on the outside, by its breadth, breaks the first violence of the waves, which otherwise, in a day, would sweep away these islets and all their productions. The ocean and the land seem here struggling for mastery ; although terra firma has obtained a footing, the denizens of the water think their claim at least equally good. In every part one meets hermit crabs of more than one species, carrying on their backs the shells which they have stolen from the neighbouring beach. Overhead, numerous gannets, frigate-birds, and terns rest on the trees ; and the wood, from the many nests and from the smell of the atmosphere, might be called a sea-rookery. The gannets, sitting on their rude nests, gaze at one with a stupid yet angry air. The noddies, as their name expresses, are silly little creatures. But there is one charming bird : it is a small snow-white tern, which smoothly hovers at the distance of a few feet above one's head, its large black eye scanning, with quiet curiosity, your expression. Little imagination is required to fancy that so light and delicate a body must be tenanted by some wandering fairy spirit.

Sunday, April 3rd.—After service I accompanied Captain Fitz Roy to the settlement, situated at the distance of some miles, on the point of an islet thickly covered with tall cocoa-nut trees. Captain Ross and Mr. Liesk live in a large barn-like house open at both ends, and lined with mats made of woven bark. The houses of the Malays are arranged along the shore of the lagoon. The whole place had rather a desolate aspect, for there were no gardens to show the signs of care and cultivation. The natives belong to different islands in the East Indian Archipelago, but all speak the same language : we saw the inhabitants of Borneo, Celebes, Java, and Sumatra. In colour they resemble the Tahitians, from whom they do not widely differ in features. Some of the women, however, show a good deal of the Chinese character. I liked both their general expressions and the sound of their voices. They appeared poor, and their houses were destitute of furniture ; but it was evident, from the plumpness of the little children, that cocoa-nuts and turtle afford no bad sustenance.

On this island the wells are situated from which ships obtain water. At first sight it appears not a little remarkable that the fresh water should regularly ebb and flow with the tides ; and it has even been imagined that sand has the power of filtering the salt from the sea-water. These ebbing wells are common on some of the low islands in the West Indies. The compressed sand, or porous coral rock, is permeated like a sponge with the salt water ; but the rain which falls on the surface must sink to the level of the surrounding sea, and must accumulate there, displacing an equal bulk of the salt water. As the water in the lower part of the great sponge-like coral mass rises and falls with the tides, so will the water near the surface ; and this will keep fresh, if the mass be sufficiently compact to prevent much mechanical admixture ; but where the

land consists of great loose blocks of coral with open interstices, if a well be dug, the water, as I have seen, is brackish.

The next day I employed myself in examining the very interesting, yet simple structure and origin of these islands. The water being unusually smooth, I waded over the outer flat of dead rock as far as the living mounds of coral, on which the swell of the open sea breaks. In some of the gullies and hollows there were beautiful green and other coloured fishes, and the forms and tints of many of the zoophytes were admirable. It is excusable to grow enthusiastic over the infinite numbers of organic beings with which the sea of the tropics, so prodigal of life, teems : yet I must confess I think those naturalists who have described, in well-known words, the submarine grottos decked with a thousand beauties have indulged in rather exuberant language.

April 6th.—I accompanied Captain Fitz Roy to an island at the head of the lagoon : the channel was exceedingly intricate, winding through fields of delicately branched corals. We saw several turtle, and two boats were then employed in catching them. The water was so clear and shallow that, although at first a turtle quickly dives out of sight, yet in a canoe or boat under sail the pursuers after no very long chase come up to it. A man standing ready in the bow at this moment dashes through the water upon the turtle's back ; then clinging with both hands by the shell of its neck, he is carried away till the animal becomes exhausted and is secured.

When we arrived at the head of the lagoon, we crossed a narrow islet, and found a great surf breaking on the windward coast. I can hardly explain the reason, but there is to my mind much grandeur in the view of the outer shores of these lagoon-islands. There is a simplicity in the barrier-like beach, the margin of

green bushes and tall cocoa-nuts, the solid flat of dead coral-rock, strewed here and there with great loose fragments, and the line of furious breakers, all rounding away towards either hand. The ocean throwing its waters over the broad reef appears an invincible, all-powerful enemy ; yet we see it resisted, and even conquered, by means which at first seem most weak and inefficient. It is not that the ocean spares the rock of coral ; the great fragments scattered over the reef, and heaped on the beach, whence the tall cocoa-nut springs, plainly bespeak the unrelenting power of the waves. Nor are any periods of repose granted. The long swell caused by the gentle but steady action of the trade wind, always blowing in one direction over a wide area, causes breakers, almost equalling in force those during a gale of wind in the temperate regions, and which never cease to rage. It is impossible to behold these waves without feeling a conviction that an island, though built of the hardest rock, let it be porphyry, granite, or quartz, would ultimately yield and be demolished by such an irresistible power. Yet these low, insignificant coral-islets stand and are victorious : for here another power, as an antagonist, takes part in the contest. The organic forces separate the atoms of carbonate of lime, one by one, from the foaming breakers, and unite them into a symmetrical structure. Let the hurricane tear up its thousand huge fragments ; yet what will that tell against the accumulated labour of myriads of architects at work night and day, month after month ? Thus do we see the soft and gelatinous body of a polypus, through the agency of the vital laws, conquering the great mechanical power of the waves of an ocean which neither the art of man nor the inanimate works of Nature could successfully resist.

We did not return on board till late in the evening, for we stayed a long time in the lagoon, examining the

1. Fringing or shore reefs
2. Barrier reef
3. Atolls

fields of coral and the gigantic shells of the chama, into which, if a man were to put his hand, he would not, as long as the animal lived, be able to withdraw it. Near the head of the lagoon, I was much surprised to find a wide area, considerably more than a mile square, covered as with a forest of delicately branching corals, which, though standing upright, were all dead and rotten. At first I was quite at a loss to understand the cause ; afterwards it occurred to me that it was owing to the following rather curious combination of circumstances. It should, however, first be stated, that corals are not able to survive even a short exposure in the air to the sun's rays, so that their upward limit of growth is determined by that of lowest water at spring tides. It appears, from some old charts, that the long island to windward was formerly separated by wide channels into several islets ; this fact is likewise indicated by the trees being younger on these portions. Under the former condition of the reef, a strong breeze, by throwing more water over the barrier, would tend to raise the level of the lagoon. Now it acts in a directly contrary manner ; for the water within the lagoon not only is not increased by currents from the outside, but is itself blown outwards by the force of the wind. Hence it is observed that the tide near the head of the lagoon does not rise so high during a strong breeze as it does when it is calm. This difference of level, although no doubt very small, has, I believe, caused the death of those coral-groves, which under the former and more open condition of the outer reef had attained the utmost possible limit of upward growth.

During another day I visited West Islet, on which the vegetation was perhaps more luxuriant than on any other. The cocoa-nut trees generally grow separate, but here the young ones flourished beneath their tall parents, and formed with their long and

curved fronds the most shady harbours. Those alone who have tried it know how delicious it is to be seated in such shade, and drink the cool pleasant fluid of the cocoa-nut. In this island there is a large bay-like space, composed of the finest white sand : it is quite level, and is only covered by the tide at high water ; from this large bay smaller creeks penetrate the surrounding woods. To see a field of glittering white sand, representing water, with the cocoa-nut trees extending their tall and waving trunks round the margin, formed a singular and very pretty view.

April 12th.—In the morning we stood out of the lagoon on our passage to the Isle of France. I am glad we have visited these islands : such formations surely rank high amongst the wonderful objects of this world. Captain Fitz Roy found no bottom with a line 7200 feet in length, at the distance of only 2200 yards from the shore ; hence this island forms a lofty submarine mountain, with sides steeper even than those of the most abrupt volcanic cone. The saucer-shaped summit is nearly ten miles across ; and every single atom, from the least particle to the largest fragment of rock, in this great pile, which however is small compared with very many other lagoon-islands, bears the stamp of having been subjected to organic arrangement. We feel surprise when travellers tell us of the vast dimensions of the Pyramids and other great ruins, but how utterly insignificant are the greatest of these, when compared to these mountains of stone accumulated by the agency of various minute and tender animals ! This is a wonder which does not at first strike the eye of the body, but, after reflection, the eye of reason.

I will now give a very brief account of the three great classes of coral-reefs ; namely, Atolls, Barrier, and Fringing Reefs, and will explain my view on their

formation. Almost every voyager who has crossed the Pacific has expressed his unbounded astonishment at the lagoon-islands, or as I shall for the future call them by their Indian name of atolls, and has attempted some explanation. Even as long ago as the year 1605, Pyrard de Laval well exclaimed, " C'est une meruille de voir chacun de ces atollons, enuironné d'un grand banc de pierre tout autour, n'y ayant point d'artifice humain." A mere sketch can give but a faint idea of the singular aspect of an atoll ; it is one of the smallest size, and has its narrow islets united together in a ring. The immensity of the ocean, the fury of the breakers, contrasted with the lowness of the land and the smoothness of the bright green water within the lagoon, can hardly be imagined without having been seen.

The earlier voyagers fancied that the coral-building animals instinctively built up their great circles to afford themselves protection in the inner parts ; but so far is this from the truth, that those massive kinds, to whose growth on the exposed outer shores the very existence of the reef depends, cannot live within the lagoon, where other delicately-branching kinds flourish. Moreover, on this view, many species of distinct genera and families are supposed to combine for one end ; and of such a combination, not a single instance can be found in the whole of Nature. The theory that has been most generally received is, that atolls are based on submarine craters ; but when we consider the form and size of some, the number, proximity, and relative positions of others, this idea loses its plausible character : thus, Suadiva atoll is forty-four geographical miles in diameter in one line, by thirty-four miles in another line ; Rimsky is fifty-four by twenty miles across, and it has a strangely sinuous margin ; Bow atoll is thirty miles long, and on an average only six in width ; Menchicoff atoll consists of three atolls united or tied together. This

theory, moreover, is totally inapplicable to the northern Maldiva atolls in the Indian Ocean (one of which is eighty-eight miles in length, and between ten and twenty in breadth), for they are not bounded like ordinary atolls by narrow reefs, but by a vast number of separate little atolls ; other little atolls rising out of the great central lagoon-like spaces. A third and better theory was advanced by Chamisso, who thought that from the corals growing more vigorously where exposed to the open sea, as undoubtedly is the case, the outer edges would grow up from the general foundation before any other part, and that this would account for the ring or cup-shaped structure. But we shall immediately see that in this, as well as in the crater-theory, a most important consideration has been overlooked, namely, on what have the reef-building corals, which cannot live at a great depth, based their massive structures ?

Numerous soundings were carefully taken by Captain Fitz Roy on the steep outside of Keeling atoll, and it was found that within ten fathoms, the prepared tallow at the bottom of the lead invariably came up marked with the impression of living corals, but as perfectly clean as if it had been dropped on a carpet of turf ; as the depth increased, the impressions became less numerous, but the adhering particles of sand more and more numerous, until at last it was evident that the bottom consisted of a smooth sandy layer : to carry on the analogy of the turf, the blades of grass grew thinner and thinner, till at last the soil was so sterile that nothing sprang from it. From these observations, confirmed by many others, it may be safely inferred that the utmost depth at which corals can construct reefs is between twenty and thirty fathoms. Now there are enormous areas in the Pacific and Indian Oceans in which every single island is of coral formation, and is raised only to that

height to which the waves can throw up fragments, and the winds pile up sand. Thus the Radack group of atolls is an irregular square, 520 miles long and 240 miles broad ; the Low Archipelago is elliptic-formed, 840 miles in its longer, and 420 in its shorter axis ; there are other small groups and single low islands between these two archipelagos, making a linear space of ocean actually more than 4000 miles in length, in which not one single island rises above the specified height. Again, in the Indian Ocean there is a space of ocean 1500 miles in length, including three archipelagos, in which every island is low and of coral formation. From the fact of the reef-building corals not living at great depths, it is absolutely certain that throughout these vast areas, wherever there is now an atoll, a foundation must have originally existed within a depth of from twenty to thirty fathoms from the surface. It is improbable in the highest degree, that broad, lofty, isolated, steep-sided banks of sediment, arranged in groups and lines hundreds of leagues in length, could have been deposited in the central and profoundest parts of the Pacific and Indian Oceans, at an immense distance from any continent, and where the water is perfectly limpid. It is equally improbable that the elevatory forces should have uplifted, throughout the above vast areas, innumerable great rocky banks within twenty to thirty fathoms, or 120 to 180 feet, of the surface of the sea, and not one single point above that level ; for where on the whole face of the globe can we find a single chain of mountains, even a few hundred miles in length, with their many summits rising within a few feet of a given level, and not one pinnacle above it ? If then the foundations, whence the atoll-building corals sprang, were not formed of sediment, and if they were not lifted up to the required level, they must of necessity have subsided into it ; and this at once solves the difficulty.

For as mountain after mountain, and island after island, slowly sank beneath the water, fresh bases would be successively afforded for the growth of the corals. It is impossible here to enter into all the necessary details, but I venture to defy any one to explain in any other manner, how it is possible that numerous islands should be distributed throughout vast areas—all the islands being low—all being built of corals, absolutely requiring a foundation within a limited depth from the surface.

Before explaining how atoll-formed reefs acquire their peculiar structure, we must turn to the second great class, namely, barrier-reefs. These either extend in straight lines in front of the shores of a continent or of a large island, or they encircle smaller islands; in both cases, being separated from the land by a broad and rather deep channel of water, analogous to the lagoon within an atoll. It is remarkable how little attention has been paid to encircling barrier-reefs; yet they are truly wonderful structures. For instance, in the barrier encircling the island of Bolabola in the Pacific, seen from one of the central peaks, the whole line of reef has been converted into land; but usually a snow-white line of great breakers, with only here and there a single low islet crowned with cocoa-nut trees, divides the dark heaving waters of the ocean from the light-green expanse of the lagoon-channel. And the quiet waters of this channel generally bathe a fringe of low alluvial soil, loaded with the most beautiful productions of the tropics, and lying at the foot of the wild, abrupt, central mountains.

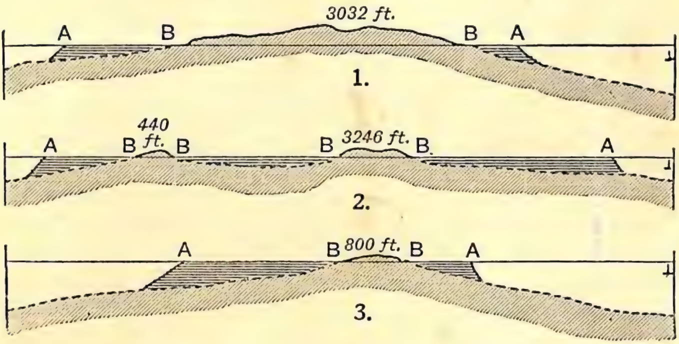
Encircling barrier-reefs are of all sizes, from three miles to no less than forty-four miles in diameter; and that which fronts one side and encircles both ends of New Caledonia is 400 miles long. Each reef includes one, two, or several rocky islands of various

heights ; and in one instance, even as many as twelve separate islands. The reef runs at a greater or less distance from the included land ; in the Society Archipelago generally from one to three or four miles ; but at Hogoleu the reef is twenty miles on the southern side, and fourteen miles on the opposite or northern side, from the included islands. The depth within the lagoon-channel also varies much ; from ten to thirty fathoms may be taken as an average; but at Vanikoro there are spaces no less than fifty-six fathoms or 336 feet deep. Internally the reef either slopes gently into the lagoon-channel, or ends in a perpendicular wall sometimes between two and three hundred feet under water in height : externally the reef rises, like an atoll, with extreme abruptness out of the profound depths of the ocean. What can be more singular than these structures ? We see an island, which may be compared to a castle situated on the summit of a lofty submarine mountain, protected by a great wall of coral rock, always steep externally and sometimes internally, with a broad level summit, here and there breached by narrow gateways, through which the largest ships can enter the wide and deep encircling moat.

As far as the actual reef of coral is concerned, there is not the smallest difference, in general size, outline, grouping, and even in quite trifling details of structure, between a barrier and an atoll. The geographer Balbi has well remarked, that an encircled island is an atoll with high land rising out of its lagoon ; remove the land from within, and a perfect atoll is left.

But what has caused these reefs to spring up at such great distances from the shores of the included islands? It cannot be that the corals will not grow close to the land ; for the shores within the lagoon-channel, when not surrounded by alluvial soil, are often fringed by living reefs ; and we shall presently see that there

is a whole class, which I have called Fringing Reefs, from their close attachment to the shores both of continents and of islands. Again, on what have the reef-building corals, which cannot live at great depths, based their encircling structure? This is a great apparent difficulty, analogous to that in the case of atolls, which has generally been overlooked. It will be perceived more clearly by inspecting the following sections, which are real ones, taken in north and south lines, through the islands with their barrier-reefs, of



1. Vanikoro. 2. Gambier Islands. 3. Maurua.

The horizontal shading shows the barrier-reefs and lagoon-channels. The inclined shading above the level of the sea (AA), shows the actual form of the land; the inclined shading below this line, shows its probable prolongation under water.

Vanikoro, Gambier, and Maurua; and they are laid down, both vertically and horizontally, on the same scale of a quarter of an inch to a mile.

It should be observed that the sections might have been taken in any direction through these islands, or through many other encircled islands, and the general features would have been the same. Now bearing in mind that reef-building coral cannot live at a greater depth than from twenty to thirty fathoms, and that

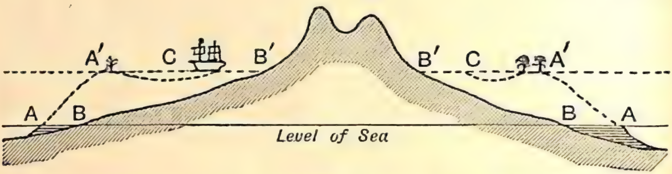
the scale is so small that the plummets on the right hand show a depth of 200 fathoms, on what are these barrier-reefs based? Are we to suppose that each island is surrounded by a collar-like submarine ledge of rock, or by a great bank of sediment, ending abruptly where the reef ends? If the sea had formerly eaten deeply into the islands, before they were protected by the reefs, thus having left a shallow ledge round them under water, the present shores would have been invariably bounded by great precipices; but this is most rarely the case. Moreover, on this notion, it is not possible to explain why the corals should have sprung up, like a wall, from the extreme outer margin of the ledge, often leaving a broad space of water within, too deep for the growth of corals. The accumulation of a wide bank of sediment all round these islands, and generally widest where the included islands are smallest, is highly improbable, considering their exposed positions in the central and deepest parts of the ocean. In the case of the barrier-reef of New Caledonia, which extends for one hundred and fifty miles beyond the northern point of the island, in the same straight line with which it fronts the west coast, it is hardly possible to believe, that a bank of sediment could thus have been straightly deposited in front of one lofty island, and so far beyond its termination in the open sea. Finally, if we look to other oceanic islands of about the same height and of similar geological constitution, but not encircled by coral-reefs, we may in vain search for so trifling a circumambient depth as thirty fathoms, except quite near to their shores; for usually land that rises abruptly out of water, as do most of the encircled and non-encircled oceanic islands, plunges abruptly under it. On what then, I repeat, are these barrier-reefs based? Why, with their wide and deep moat-like channels, do they stand so far from the included

land? We shall soon see how easily these difficulties disappear.

We come now to our third class of Fringing Reefs, which will require a very short notice. Where the land slopes abruptly under water these reefs are only a few yards in width, forming a mere ribbon or fringe round the shores: where the land slopes gently under the water the reef extends further, sometimes even as much as a mile from the land; but in such cases the soundings outside the reef always show that the submarine prolongation of the land is gently inclined. In fact, the reefs extend only to that distance from the shore at which a foundation within the requisite depth, from twenty to thirty fathoms, is found. As far as the actual reef is concerned there is no essential difference between it and that forming a barrier or an atoll; it is, however, generally of less width, and consequently few islets have been formed on it. From the corals growing more vigorously on the outside, and from the noxious effect of the sediment washed inwards, the outer edge of the reef is the highest part, and between it and the land there is generally a shallow sandy channel a few feet in depth. Where banks of sediment have accumulated near to the surface, as in parts of the West Indies, they sometimes become fringed with corals, and hence in some degree resemble lagoon-islands or atolls in the same manner as Fringing Reefs, surrounding gently-sloping islands, in some degree resemble barrier-reefs.

No theory on the formation of coral-reefs can be considered satisfactory which does not include the three great classes. We have seen that we are driven to believe in the subsidence of those vast areas, interspersed with low islands, of which not one rises above the height to which the wind and waves can throw

up matter, and yet are constructed by animals requiring a foundation, and that foundation to lie at no great depth. Let us then take an island surrounded by fringing-reefs, which offer no difficulty in their structure ; and let this island with its reef, represented by the unbroken lines in the woodcut, slowly subside. Now, as the island sinks down, either a few feet at a time or quite insensibly, we may safely infer, from what is known of the conditions favourable to the growth of coral, that the living masses, bathed by the surf on the margin of the reef, will soon regain



AA. Outer edges of the Fringing Reef, at the level of the sea. BB. The shores of the fringed island.

A′A′. Outer edges of the reef, after its upward growth during a period of subsidence, now converted into a barrier, with islets on it. B′B′. The shores of the now encircled island. CC. Lagoon-channel.

N.B.—In this and the following woodcut, the subsidence of the land could be represented only by an apparent rise in the level of the sea.

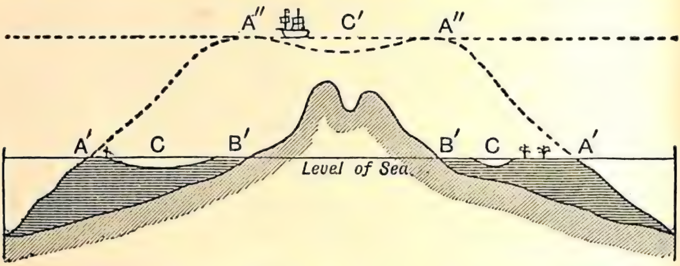
the surface. The water, however, will encroach little by little on the shore, the island becoming lower and smaller, and the space between the inner edge of the reef and the beach proportionally broader. A section of the reef and island in this state, after a subsidence of several hundred feet, is given by the dotted lines. Coral islets are supposed to have been formed on the reef, and a ship is anchored in the lagoon-channel. This channel will be more or less deep, according to the rate of subsidence, to the amount of sediment accumulated in it, and to the growth of

the delicately branched corals which can live there. The section in this state resembles in every respect one drawn through an encircled island ; in fact, it is a real section (on the scale of ·517 of an inch to a mile) through Bolabola in the Pacific. We can now at once see why encircling barrier-reefs stand so far from the shores which they front. We can also perceive that a line drawn perpendicularly down from the outer edge of the new reef to the foundation of solid rock beneath the old Fringing Reef, will exceed by as many feet as there have been feet of subsidence, that small limit of depth at which the effective corals can live : the little architects having built up their great wall-like mass, as the whole sank down, upon a basis formed of other corals and their consolidated fragments. Thus the difficulty on this head, which appeared so great, disappears.

If, instead of an island, we had taken the shore of a continent fringed with reefs, and had imagined it to have subsided, a great straight barrier, like that of Australia or New Caledonia, separated from the land by a wide and deep channel, would evidently have been the result.

Let us take our new encircling barrier-reef, of which the section is now represented by unbroken lines, and which, as I have said, is a real section, through Bolabola, and let it go on subsiding. As the barrier-reef slowly sinks down, the corals will go on vigorously growing upwards ; but as the island sinks, the water will gain inch by inch on the shore—the separate mountains first forming separate islands within one great reef—and finally, the last and highest pinnacle disappearing. The instant this takes place, a perfect atoll is formed : I have said, remove the high land from within an encircling barrier-reef, and an atoll is left, and the land has been removed. We can now perceive how it comes that atolls, having

sprung from encircling barrier-reefs, resemble them in general size, form, in the manner in which they are grouped together, and in their arrangement in single or double lines; for they may be called rude outline charts of the sunken islands over which they stand. We can further see how it arises that the atolls in the Pacific and Indian Oceans extend in lines parallel to the generally prevailing strike of the high islands



A′A′. Outer edges of the barrier-reef at the level of the sea, with islets on it. B′B′. The shores of the included island. CC. The lagoon-channel.

A″A″. Outer edges of the reef, now converted into an atoll. C′. The lagoon of the new atoll.

N.B.—According to the true scale, the depths of the lagoon-channel and lagoon are much exaggerated.

and great coast-lines of those oceans. I venture, therefore, to affirm that on the theory of the upward growth of the corals during the sinking of the land, all the leading features in those wonderful structures, the lagoon-islands or atolls, which have so long excited the attention of voyagers, as well as in the no less wonderful barrier-reefs, whether encircling small islands or stretching for hundreds of miles along the shores of a continent, are simply explained.

It may be asked whether I can offer any direct evidence of the subsidence of barrier-reefs or atolls; but it must be borne in mind how difficult it must ever be to detect a movement the tendency of which

is to hide under water the part affected. Nevertheless, at Keeling atoll I observed on all sides of the lagoon old cocoa-nut trees undermined and falling; and in one place the foundation posts of a shed, which the inhabitants asserted had stood seven years before just above high-water mark, but now was daily washed by every tide: on inquiry I found that three earthquakes, one of them severe, had been felt here during the last ten years. At Vanikoro, the lagoon-channel is remarkably deep, scarcely any alluvial soil has accumulated at the foot of the lofty included mountains, and remarkably few islets have been formed by the heaping of fragments and sand on the wall-like barrier-reef; these facts, and some analogous ones, led me to believe that this island must lately have subsided and the reef grown upwards: here again earthquakes are frequent and very severe. In the Society Archipelago, on the other hand, where the lagoon-channels are almost choked up, where much low alluvial land has accumulated, and where in some cases long islets have been formed on the barrier-reefs—facts all showing that the islands have not very lately subsided—only feeble shocks are most rarely felt. In these coral formations, where the land and water seem struggling for mastery, it must be ever difficult to decide between the effects of a change in the set of the tides and of a slight subsidence: that many of these reefs and atolls are subject to changes of some kind is certain; on some atolls the islets appear to have increased greatly within a late period; on others they have been partially or wholly washed away. The inhabitants of parts of the Maldiva Archipelago know the date of the first formation of some islets; in other parts the corals are now flourishing on water-washed reefs, where holes made for graves attest the former existence of inhabited land. It is difficult to believe in frequent changes in the tidal

currents of an open ocean ; whereas, we have in the earthquakes recorded by the natives on some atolls, and in the great fissures observed on other atolls, plain evidence of changes and disturbances in progress in the subterranean regions.

It is evident, on our theory, that coasts merely fringed by reefs cannot have subsided to any perceptible amount ; and therefore they must, since the growth of their corals, either have remained stationary or have been upheaved. Now it is remarkable how generally it can be shown, by the presence of upraised organic remains, that the fringed islands have been elevated ; and so far, this is indirect evidence in favour of our theory. I was particularly struck with this fact, when I found, to my surprise, that the descriptions given by MM. Quoy and Gaimard were applicable, not to reefs in general as implied by them, but only to those of the fringing-class ; my surprise, however, ceased when I afterwards found that, by a strange chance, all the several islands visited by these eminent naturalists could be shown by their own statements to have been elevated within a recent geological era.

Not only the grand features in the structure of barrier-reefs and of atolls, and of their likeness to each other in form, size, and other characters, are explained on the theory of subsidence—which theory we are independently forced to admit in the very areas in question, from the necessity of finding bases for the corals within the requisite depth—but many details in structure and exceptional cases can thus also be simply explained. I will give only a few instances. In barrier-reefs it has long been remarked with surprise that the passages through the reef exactly face valleys in the included land, even in cases where the reef is separated from the land by a lagoon-channel so wide and so much deeper than the actual passage

itself, that it seems hardly possible that the very small quantity of water or sediment brought down could injure the corals on the reef. Now, every reef of the fringing-class is breached by a narrow gateway in front of the smallest rivulet, even if dry during the greater part of the year, for the mud, sand, or gravel, occasionally washed down, kills the corals on which it is deposited. Consequently, when an island thus fringed subsides, though most of the narrow gateways will probably become closed by the outward and upward growth of the corals, yet any that are not closed (and some must always be kept open by the sediment and impure water flowing out of the lagoon-channel) will still continue to front exactly the upper parts of those valleys at the mouths of which the original basal fringing-reef was breached.

We can easily see how an island fronted only on one side, or on one side with one end or both ends encircled by barrier-reefs, might after long-continued subsidence be converted either into a single wall-like reef, or into an atoll with a great straight spur projecting from it, or into two or three atolls tied together by straight reefs—all of which exceptional cases actually occur. As the reef-building corals require food, are preyed upon by other animals, are killed by sediment, cannot adhere to a loose bottom, and may be easily carried down to a depth whence they cannot spring up again, we need feel no surprise at the reefs both of atolls and barriers becoming in parts imperfect. The great barrier of New Caledonia is thus imperfect and broken in many parts ; hence, after long subsidence, this great reef would not produce one great atoll four hundred miles in length, but a chain or archipelago of atolls, of very nearly the same dimensions with those in the Maldiva Archipelago. Moreover, in an atoll once breached on opposite sides, from the likelihood of the oceanic and tidal currents passing straight

through the breaches, it is extremely improbable that the corals, especially during continued subsidence, would ever be able again to unite the rim ; if they did not, as the whole sank downwards, one atoll would be divided into two or more. In the Maldiva Archipelago there are distinct atolls so related to each other in position, and separated by channels either unfathomable or very deep (the channel between Ross and Ari atolls is 150 fathoms, and that between the north and south Nillandoo atolls is 200 fathoms in depth), that it is impossible to look at a map of them without believing that they were once more intimately related. And in this same archipelago, Mahlos-Mahdoo atoll is divided by a bifurcating channel from 100 to 132 fathoms in depth, in such a manner that it is scarcely possible to say whether it ought strictly to be called three separate atolls, or one great atoll not yet finally divided.

I will not enter on many more details ; but I must remark that the curious structure of the northern Maldiva atolls receives (taking into consideration the free entrance of the sea through their broken margins) a simple explanation in the upward and outward growth of the corals, originally based both on small detached reefs in their lagoons, such as occur in common atolls, and on broken portions of the linear marginal reef, such as bounds every atoll of the ordinary form. I cannot refrain from once again remarking on the singularity of these complex structures—a great sandy and generally concave disc rises abruptly from the unfathomable ocean, with its central expanse studded, and its edge symmetrically bordered with oval basins of coral-rock just lipping the surface of the sea, sometimes clothed with vegetation, and each containing a lake of clear water !

One more point in detail : as in two neighbouring archipelagos corals flourish in one and not in the

other, and as so many conditions before enumerated must affect their existence, it would be an inexplicable fact if, during the changes to which earth, air, and water are subjected, the reef-building corals were to keep alive for perpetuity on any one spot or area. And as by our theory the areas including atolls and barrier-reefs are subsiding, we ought occasionally to find reefs both dead and submerged. In all reefs, owing to the sediment being washed out of the lagoon or lagoon-channel to leeward, that side is least favourable to the long-continued vigorous growth of the corals ; hence, dead portions of reef not unfrequently occur on the leeward side ; and these, though still retaining their proper wall-like form, are now in several instances sunk several fathoms beneath the surface. The Chagos group appears from some cause, possibly from the subsidence having been too rapid, at present to be much less favourably circumstanced for the growth of reefs than formerly : one atoll has a portion of its marginal reef, nine miles in length, dead and submerged ; a second has only a few quite small living points which rise to the surface ; a third and fourth are entirely dead and submerged ; a fifth is a mere wreck, with its structure almost obliterated. It is remarkable that in all these cases the dead reefs and portions of reef lie at nearly the same depth, namely, from six to eight fathoms beneath the surface, as if they had been carried down by one uniform movement. One of these " half-drowned atolls," so called by Captain Moresby (to whom I am indebted for much invaluable information), is of vast size, namely, ninety nautical miles across in one direction, and seventy miles in another line ; and is in many respects eminently curious. As by our theory it follows that new atolls will generally be formed in each new area of subsidence, two weighty objections might have been raised, namely, that atolls must be increasing

indefinitely in number ; and secondly, that in old areas of subsidence each separate atoll must be increasing indefinitely in thickness, if proofs of their occasional destruction could not have been adduced. Thus have we traced the history of these great rings of coral-rock, from their first origin through their normal changes, and through occasional accidents of their existence, to their death and final obliteration. Bearing in mind the statements made with respect to the upraised organic remains, we must feel astonished at the vastness of the areas which have suffered changes in level either downwards or upwards, within a period not geologically remote. It would appear, also, that the elevatory and subsiding movements follow nearly the same laws. Throughout the spaces interspersed with atolls, where not a single peak of high land has been left above the level of the sea, the sinking must have been immense in amount. The sinking, moreover, whether continuous, or recurrent with intervals sufficiently long for the corals again to bring up their living edifices to the surface, must necessarily have been extremely slow. This conclusion is probably the most important one which can be deduced from the study of coral formations ; and it is one which it is difficult to imagine how otherwise could have been arrived at. Nor can I quite pass over the probability of the former existence of large archipelagos of lofty islands, where now only rings of coral-rock scarcely break the open expanse of the sea, throwing some light on the distribution of the inhabitants of the other high islands now left standing so immensely remote from each other in the midst of the great oceans. The reef-constructing corals have indeed reared and preserved wonderful memorials of the subterranean oscillations of level ; we see in each barrier-reef a proof that the land has there subsided, and in each atoll a monument over an island now lost.

CORAL FORMATIONS

We may thus, like unto a geologist who had lived his ten thousand years and kept a record of the passing changes, gain some insight into the great system by which the surface of this globe has been broken up, and land and water interchanged.

CHARLES DARWIN

NATURAL HISTORY

MARTINS AND SWALLOWS

SELBORNE, *Nov.* 20, 1773

DEAR SIR—In obedience to your injunctions I sit down to give you some account of the house-martin, or martlet; and, if my monography of this little domestic and familiar bird should happen to meet with your approbation, I may probably soon extend my inquiries to the rest of the British *hirundines*—the swallow, the swift, and the bank-martin.

A few house-martins begin to appear about the sixteenth of April; usually some few days later than the swallow. For some time after they appear the *hirundines* in general pay no attention to the business of nidification, but play and sport about either to recruit from the fatigue of their journey, if they do migrate at all, or else that their blood may recover its true tone and texture after it has been so long benumbed by the severities of winter. About the middle of May, if the weather be fine, the martin begins to think in earnest of providing a mansion for its family. The crust or shell of this nest seems to be formed of such dirt or loam as comes most readily to hand, and is tempered and wrought together with little bits of broken straws to render it tough and tenacious. As this bird often builds against a perpendicular wall without any projecting ledge under, it requires its utmost efforts to get the first foundation firmly fixed, so that it may safely carry the superstructure. On this occasion the bird not only clings with its claws, but partly supports itself by strongly inclining its tail

against the wall, making that a fulcrum ; and thus steadied it works and plasters the materials into the face of the brick or stone. But then, that this work may not, while it is soft and green, pull itself down by its own weight, the provident architect has prudence and forbearance enough not to advance her work too fast ; but by building only in the morning, and by dedicating the rest of the day to food and amusement, gives it sufficient time to dry and harden. About half an inch seems to be a sufficient layer for a day. Thus careful workmen when they build mud-walls (informed at first perhaps by this little bird) raise but a moderate layer at a time, and then desist ; lest the work should become top-heavy, and so be ruined by its own weight. By this method in about ten or twelve days is formed a hemispheric nest with a small aperture towards the top, strong, compact, and warm ; and perfectly fitted for all the purposes for which it was intended. But then nothing is more common than for the house-sparrow, as soon as the shell is finished, to seize on it as its own, to eject the owner, and to line it after its own manner.

After so much labour is bestowed in erecting a mansion, as nature seldom works in vain, martins will breed on for several years together in the same nest, where it happens to be well sheltered and secure from the injuries of weather. The shell or crust of the nest is a sort of rustic work full of knobs and protuberances on the outside : nor is the inside of those that I have examined smoothed with any exactness at all ; but is rendered soft and warm, and fit for incubation, by a lining of small straws, grasses, and feathers ; and sometimes by a bed of moss interwoven with wool.

As the young of small birds presently arrive at their ἡλικία or full growth, they soon become impatient of confinement, and sit all day with their heads out at the orifice, where the dams, by clinging to the nest,

supply them with food from morning to night. For a time the young are fed on the wing by their parents; but the feat is done by so quick and almost imperceptible a sleight, that a person must have attended very exactly to their motions before he would be able to perceive it. As soon as the young are able to shift for themselves, the dams immediately turn their thoughts to the business of a second brood: while the first flight, shaken off and rejected by their nurses, congregate in great flocks, and are the birds that are seen clustering and hovering on sunny mornings and evenings round towers and steeples, and on the roofs of churches and houses. These congregatings usually begin to take place about the first week in August; and therefore we may conclude that by that time the first flight is pretty well over. The young of this species do not quit their abodes all together; but the more forward birds get abroad some days before the rest. These approaching the eaves of buildings, and playing about before them, make people think that several old ones attend one nest. They are often capricious in fixing on a nesting place, beginning many edifices, and leaving them unfinished; but when once a nest is completed in a sheltered place, it serves for several seasons. Those which breed in a ready finished house get the start in hatching of those that build new by ten days or a fortnight. These industrious artificers are at their labours in the long days before four in the morning: when they fix their materials they plaster them on with their chins, moving their heads with a quick vibratory motion. They dip and wash as they fly sometimes in very hot weather, but not so frequently as swallows. It has been observed that martins usually build to a north-east or north-west aspect, that the heat of the sun may not crack and destroy their nests: but instances are also remembered where they bred for many years in vast

abundance in a hot stifled inn-yard, against a wall facing to the south.

Birds in general are wise in their choice of situation: but in this neighbourhood every summer is seen a strong proof to the contrary at a house without the eaves in an exposed district, where some martins build year by year in the corners of the windows. But, as the corners of these windows (which face to the south-east and south-west) are too shallow, the nests are washed down every hard rain; and yet these birds drudge on to no purpose from summer to summer, without changing their aspect or house. It is a piteous sight to see them labouring when half their nest is washed away and bringing dirt. Thus is instinct a most wonderful unequal faculty; in some instances so much above reason, in other respects so far below it! Martins love to frequent towns, especially if there are great lakes and rivers at hand; nay they even affect the close air of London. And I have not only seen them nesting in the Borough, but even in the Strand and Fleet Street; but then it was obvious from the dinginess of their aspect that their feathers partook of the filth of that sooty atmosphere. Martins are by far the least agile of the four species; their wings and tails are short, and therefore they are not capable of such surprising turns and quick and glancing evolutions as the swallow. Accordingly they make use of a placid easy motion in a middle region of the air, seldom mounting to any great height, and never sweeping long together over the surface of the ground or water. They do not wander far for food, but affect sheltered districts, over some lake, or under some hanging wood, or in some hollow vale, especially in windy weather. They breed the latest of all the swallow kind: in 1772 they had nestlings on to October the twenty-first, and are never without unfledged young as late as Michaelmas.

As the summer declines the congregating flocks increase in numbers daily by the constant accession of the second broods ; till at last they swarm in myriads upon myriads round the villages on the Thames, darkening the face of the sky as they frequent the aits of that river, where they roost. They retire, the bulk of them I mean, in vast flocks together about the beginning of October : but have appeared of late years in a considerable flight in this neighbourhood, for one day or two, as late as November the third and sixth, after they were supposed to have been gone for more than a fortnight. They therefore withdraw with us the latest of any species. Unless these birds are very short-lived indeed, or unless they do not return to the district where they are bred, they must undergo vast devastations somehow, and somewhere ; for the birds that return yearly bear no manner of proportion to the birds that retire.

House-martins are distinguished from their congeners by having their legs covered with soft downy feathers down to their toes. They are no songsters ; but twitter in a pretty inward soft manner in their nests.

I am, etc.

. . . . . .

SELBORNE, *Jan.* 29, 1774

DEAR SIR—The house-swallow, or chimney-swallow, is undoubtedly the first comer of all the British *hirundines*, and appears in general on or about the thirteenth of April, as I have remarked from many years' observation. Not but now and then a straggler is seen much earlier : and, in particular, when I was a boy I observed a swallow for a whole day together on a sunny warm Shrove Tuesday ; which day could not fall out later than the middle of March, and often happened early in February.

It is worth remarking that these birds are seen first about lakes and mill-ponds; and it is also very particular, that if these early visitors happen to find frost and snow, as was the case of the two dreadful springs of 1770 and 1771, they immediately withdraw for a time. A circumstance this much more in favour of hiding than migration; since it is much more probable that a bird should retire to its hybernaculum just at hand, than return for a week or two only to warmer latitudes.

The swallow, though called the chimney-swallow, by no means builds altogether in chimneys, but often within barns and out-houses against the rafters.

In Sweden she builds in barns, and is called *ladu swala*, the barn-swallow. Besides, in the warmer parts of Europe there are no chimneys to houses, except they are English-built: in these countries she constructs her nest in porches, and gateways, and galleries, and open halls.

Here and there a bird may affect some odd, peculiar place; as we have known a swallow build down the shaft of the old well, through which chalk had been formerly drawn up for the purpose of manure: but in general with us this *hirundo* breeds in chimneys; and loves to haunt those stacks where there is a constant fire, no doubt for the sake of warmth. Not that it can subsist in the immediate shaft where there is a fire; but prefers one adjoining to that of the kitchen, and disregards the perpetual smoke of that funnel, as I have often observed with some degree of wonder.

Five or six or more feet down the chimney does this little bird begin to form her nest about the middle of May, which consists, like that of the house-martin, of a crust or shell composed of dirt or mud, mixed with short pieces of straw to render it tough and permanent; with this difference, that whereas the shell of the martin is nearly hemispheric, that of the swallow is open at the top, and like half a deep dish: this nest

is lined with fine grasses and feathers which are often collected as they float in the air.

Wonderful is the address which this adroit bird shows all day long in ascending and descending with security through so narrow a pass. When hovering over the mouth of the funnel, the vibrations of her wings acting on the confined air occasion a rumbling like thunder. It is not improbable that the dam submits to this inconvenient situation so low in the shaft in order to secure her broods from rapacious birds, and particularly from owls, which frequently fall down chimneys, perhaps in attempting to get at these nestlings.

The swallow lays from four to six white eggs, dotted with red specks ; and brings out her first brood about the last week in June, or the first week in July. The progressive method by which the young are introduced into life is very amusing : first, they emerge from the shaft with difficulty enough, and often fall down into the rooms below : for a day or so they are fed on the chimney-top, and then are conducted to the dead leafless bough of some tree, where, sitting in a row, they are attended with great assiduity, and may then be called perchers. In a day or two more they become flyers, but are still unable to take their own food ; therefore they play about near the place where the dams are hawking for flies ; and when a mouthful is collected, at a certain signal given, the dam and the nestling advance, rising towards each other, and meeting at an angle ; the young one all the while uttering such a little quick note of gratitude and complacency that a person must have paid very little regard to the wonders of Nature that has not often remarked this feat.

The dam betakes herself immediately to the business of a second brood as soon as she is disengaged from her first ; which at once associates with the first

broods of house-martins ; and with them congregates, clustering on sunny roofs, towers, and trees. This *hirundo* brings out her second brood towards the middle and end of August.

All the summer long is the swallow a most instructive pattern of unwearied industry and affection ; for, from morning to night, while there is a family to be supported, she spends the whole day in skimming close to the ground, and exerting the most sudden turns and quick evolutions. Avenues, and long walks under hedges, and pasture-fields, and mown meadows where cattle graze, are her delight, especially if there are trees interspersed ; because at such spots insects most abound. When a fly is taken a smart snap from her bill is heard, resembling the noise at the shutting of a watch-case ; but the motion of the mandibles is too quick for the eye.

The swallow, probably the male bird, is the *excubitor* to house-martins and other little birds, announcing the approach of birds of prey. For as soon as a hawk appears, with a shrill alarming note he calls all the swallows and martins about him ; who pursue in a body, and buffet and strike their enemy till they have driven him from the village, darting down from above on his back, and rising in a perpendicular line in perfect security. This bird also will sound the alarm, and strike at cats when they climb on the roofs of houses or otherwise approach the nests. Each species of *hirundo* drinks as it flies along, sipping the surface of the water ; but the swallow alone, in general, washes on the wing, by dropping into a pool for many times together : in very hot weather house-martins and bank-martins dip and wash a little.

The swallow is a delicate songster, and in soft sunny weather sings both perching and flying ; on trees in a kind of concert, and on chimney-tops : is also a bold flyer, ranging to distant downs and commons even in

windy weather, which the other species seem much to dislike; nay, even frequenting exposed seaport towns, and making little excursions over the salt water. Horsemen on wide downs are often closely attended by a little party of swallows for miles together, which plays before and behind them, sweeping around, and collecting all the skulking insects that are roused by the trampling of the horses' feet: when the wind blows hard, without this expedient, they are often forced to settle to pick up their lurking prey.

This species feeds much on little *coleoptera*, as well as on gnats and flies: and often settles on dug ground, or paths, for gravels to grind and digest its food. Before they depart, for some weeks, to a bird, they forsake houses and chimneys, and roost in trees; and usually withdraw about the beginning of October; though some few stragglers may appear on at times till the first week in November.

Some few pairs haunt the new and open streets of London next the fields, but do not enter, like the house-martin, the close and crowded parts of the city.

Both male and female are distinguished from their congeners by the length and forkedness of their tails. They are undoubtedly the most nimble of all the species: and when the male pursues the female in amorous chase they then go beyond their usual speed, and exert a rapidity almost too quick for the eye to follow.

. . . . . .

SELBORNE, *Feb.* 26, 1774

DEAR SIR—The sand-martin, or bank-martin, is by much the least of any of the British *hirundines*; and, as far as we have ever seen, the smallest known *hirundo*; though Brisson asserts that there is one much smaller, and that is the *hirundo esculenta*.

But it is much to be regretted that it is scarce possible for any observer to be so full and exact as he could wish in reciting the circumstances attending the life and conversation of this little bird, since it is *fera natura*, at least in this part of the kingdom, disclaiming all domestic attachments, and haunting wild heaths and commons where there are large lakes ; while the other species, especially the swallow and house-martin, are remarkably gentle and domesticated, and never seem to think themselves safe but under the protection of man.

Here are in this parish, in the sand-pits and banks of the lakes of Wolmer Forest, several colonies of these birds, and yet they are never seen in the village ; nor do they at all frequent the cottages that are scattered about in that wild district. The only instance I ever remember where this species haunts any building is at the town of Bishop's Waltham, in this country, where many sand-martins nestle and breed in the scaffold-holes of the back-wall of William of Wykeham's stables : but then this wall stands in a very sequestered and retired enclosure, and faces upon a large and beautiful lake. And indeed this species seems so to delight in large waters, that no instance occurs of their abounding, but near vast pools or rivers : and in particular it has been remarked that they swarm in the banks of the Thames in some places below London Bridge.

It is curious to observe with what different degrees of architectonic skill Providence has endowed birds of the same genus, and so nearly correspondent in their general mode of life ! for while the swallow and the house-martin discover the greatest address in raising and securely fixing crusts or shells of loam as *cunabula* for their young, the bank-martin terebrates a round and regular hole in the sand or earth, which is serpentine, horizontal, and about two feet deep.

At the inner end of this burrow does this bird deposit, in a good degree of safety, her rude nest, consisting of fine grasses and feathers, usually goose-feathers, very inartificially laid together.

Perseverance will accomplish anything : though at first one would be disinclined to believe that this weak bird, with her soft and tender bill and claws, should ever be able to bore the stubborn sand-bank without entirely disabling herself ; yet with these feeble instruments have I seen a pair of them make great dispatch : and could remark how much they had scooped that day by the fresh sand which ran down the bank, and was of a different colour from that which lay loose and bleached in the sun.

In what space of time these little artists are able to mine and finish these cavities I have never been able to discover, for reasons given above ; but it would be a matter worthy of observation where it falls in the way of any naturalist to make his remarks. This I have often taken notice of, that several holes of different depths are left unfinished at the end of summer. To imagine that these beginnings were intentionally made in order to be in the greater forwardness for next spring, is allowing perhaps too much foresight and *rerum prudentia* to a simple bird. May not the cause of these *latebrae* being left unfinished arise from their meeting in those places with strata too harsh, hard, and solid for their purpose, which they relinquish, and go to a fresh spot that works more freely ? Or may they not in other places fall in with a soil as much too loose and mouldering, liable to flounder, and threatening to overwhelm them and their labours ?

The following circumstance should by no means be omitted—that these birds do *not* make use of their caverns by way of hybernacula, as might be expected; since banks so perforated have been dug out with care

in the winter, when nothing was found but empty nests.

The sand-martin arrives much about the same time with the swallow, and lays, as she does, from four to six white eggs. But as this species is *cryptogame*, carrying on the business of nidification, incubation, and the support of its young in the dark, it would not be so easy to ascertain the time of breeding, were it not for the coming forth of the broods, which appear much about the time or rather somewhat earlier than those of the swallow. The nestlings are supported in common, like those of their congeners, with gnats and other small insects ; and sometimes they are fed with *libellulae* (dragon-flies) almost as long as themselves. In the last week in June we have seen a row of these sitting on a rail near a great pool as perchers ; and so young and helpless as easily to be taken by hand : but whether the dams ever feed them on the wing, as swallows and house-martins do, we have never yet been able to determine ; nor do we know whether they pursue and attack birds of prey.

When they happen to breed near hedges and enclosures they are dispossessed of their breeding holes by the house-sparrow, which is on the same account a fell adversary to house-martins.

These *hirundines* are no songsters, but rather mute, making only a little harsh noise when a person approaches their nests. They seem not to be of a sociable turn, never with us congregating with their congeners in the autumn. Undoubtedly they breed a second time, like the house-martin and swallow ; and withdraw about Michaelmas.

Though in some particular districts they may happen to abound, yet in the whole, in the south of England at least, is this much the rarest species. For there are few towns or large villages but what abound with house-martins ; few churches, towers,

or steeples but what are haunted by some swifts; scarce a hamlet or single cottage-chimney that has not its swallow; while the bank-martins, scattered here and there, live a sequestered life among some abrupt sand-hills, and in the banks of some few rivers.

These birds have a peculiar manner of flying; flitting about with odd jerks, and vacillations, not unlike the motions of a butterfly. Doubtless the flight of all *hirundines* is influenced by and adapted to the peculiar sort of insects which furnish their food. Hence it would be worth inquiry to examine what particular group of insects affords the principal food of each respective species of swallow.

Notwithstanding what has been advanced above, some few sand-martins, I see, haunt the skirts of London, frequenting the dirty pools in Saint George's-Fields, and about Whitechapel. The question is where these build, since there are no banks or bold shores in that neighbourhood: perhaps they nestle in the scaffold-holes of some old or new deserted building. They dip and wash as they fly sometimes, like the house-martin and swallow.

Sand-martins differ from their congeners in the diminutiveness of their size and in their colour, which is what is usually called a mouse-colour. Near Valencia in Spain, they are taken, says Willughby, and sold in the markets for the table; and are called by the country people, probably from their desultory jerking manner of flight, *papilion di montagna*.

. . . .

SELBORNE, *Sept.* 28, 1774

DEAR SIR—As the swift or black martin is the largest of the British *hirundines*, so is it undoubtedly the latest comer. For I remember but one instance of its appearing before the last week in April: and in some of our late frosty, harsh springs it has not

been seen till the beginning of May. This species usually arrives in pairs.

The swift, like the sand-martin, is very defective in architecture, making no crust, or shell, for its nest, but forming it of dry grasses and feathers, very rudely and inartificially put together. With all my attention to these birds, I have never been able once to discover one in the act of collecting or carrying in materials : so that I have suspected (since their nests are exactly the same) that they sometimes usurp upon the house-sparrows, and expel them, as sparrows do the house- and sand-martin ; well remembering that I have seen them squabbling together at the entrance of their holes, and the sparrows up in arms and much disconcerted at these intruders. And yet I am assured, by a nice observer in such matters, that they do collect feathers for their nests in Andalusia ; and that he has shot them with such materials in their mouths.

Swifts, like sand-martins, carry on the business of nidification quite in the dark, in crannies of castles, and towers, and steeples, and upon the tops of the walls of churches under the roof ; and therefore cannot be so narrowly watched as those species that build more openly : but, from what I could ever observe, they begin nesting about the middle of May ; and I have remarked, from eggs taken, that they have sat hard by the ninth of June. In general they haunt tall buildings, churches, and steeples, and breed only in such : yet in this village some pairs frequent the lowest and meanest cottages, and educate their young under those thatched roofs. We remember but one instance where they breed out of buildings ; and that is in the sides of a deep chalk-pit near the town of Odiham, in this county, where we have seen many pairs entering the crevices, and skimming and squeaking round the precipices.

This *hirundo* differs widely from its congeners in

laying invariably but two eggs at a time, which are milk-white, long, and peaked at the small end; whereas the other species lay at each brood from four to six. It is a most alert bird, rising very early, and retiring to roost very late; and is on the wing in the height of summer at least sixteen hours. In the longest days it does not withdraw to rest till a quarter before nine in the evening, being the latest of all day birds. Just before they retire whole groups of them assemble high in the air, and squeak and shoot about with wonderful rapidity. But this bird is never so much alive as in sultry thundery weather, when it expresses great alacrity, and calls forth all its powers. On hot mornings several, getting together in little parties, dash round the steeples and churches, squeaking as they go in a very clamorous manner; these, by nice observers, are supposed to be males serenading their sitting hens; and not without reason, since they seldom squeak till they come close to the walls or eaves, and since those within utter at the same time a little inward note of complacency.

When the hen has sat hard all day, she rushes forth just as it is almost dark, and stretches and relieves her weary limbs, and snatches a scanty meal for a few minutes, and then returns to her duty of incubation. Swifts, when wantonly and cruelly shot while they have young, discover a little lump of insects in their mouths, which they pouch and hold under their tongue. In general they feed in a much higher district than the other species; a proof that gnats and other insects do also abound to a considerable height in the air: they also range to vast distances, since locomotion is no labour to them, who are endowed with such wonderful powers of wing. Their powers seem to be in proportion to their levers; and their wings are longer in proportion than those of almost any other bird.

At some certain times in the summer I had remarked that swifts were hawking very low for hours together over pools and streams ; and could not help inquiring into the object of their pursuit that induced them to descend so much below their usual range. After some trouble, I found that they were taking *phryganeae*, *ephemerae*, and *libellulae* (cadew-flies, may-flies, and dragon-flies) that were just emerged out of their aurelia state. I then no longer wondered that they should be so willing to stoop for a prey that afforded them such plentiful and succulent nourishment.

They bring out their young about the middle or latter end of July : but as these never become perchers, nor, that ever I could discern, are fed on the wing by their dams, the coming forth of the young is not so notorious as in the other species.

On the thirtieth of last June I untiled the eaves of a house where many pairs build, and found in each nest only two squab naked *pulli* : on the eighth of July I repeated the same inquiry, and found they had made very little progress towards a fledged state, but were still naked and helpless. From whence we may conclude that birds whose way of life keeps them perpetually on the wing would not be able to quit their nest till the end of the month. Swallows and martins, that have numerous families, are continually feeding them every two or three minutes ; while swifts, that have but two young to maintain, are much at their leisure, and do not attend on their nests for hours together.

Sometimes they pursue and strike at hawks that come in their way ; but not with that vehemence and fury that swallows express on the same occasion. They are out all day long in wet days, feeding about, and disregarding still rain : from whence two things may be gathered ; first, that many insects abide high in the air, even in rain ; and next, that the feathers

of these birds must be well preened to resist so much wet. Windy, and particularly windy weather with heavy showers, they dislike ; and on such days withdraw and are scarce ever seen.

There is a circumstance respecting the colour of swifts which seems not to be unworthy our attention. When they arrive in the spring they are all over of a glossy, dark soot-colour, except their chins, which are white ; but, by being all day long in the sun and air, they become quite weather-beaten and bleached before they depart, and yet they return glossy again in the spring. Now, if they pursue the sun into lower latitudes, as some suppose, in order to enjoy a perpetual summer, why do they not return bleached ? Do they not rather perhaps retire to rest for a season, and at that juncture moult and change their feathers, since all other birds are known to moult soon after the season of breeding ?

Swifts are very anomalous in many particulars, dissenting from all their congeners not only in the number of their young but in breeding but once in a summer ; whereas all the other British *hirundines* breed invariably twice. It is past all doubt that swifts can breed but once, since they withdraw in a short time after the flight of their young, and some time before their congeners bring out their second brood. We may here remark, that, as swifts breed but once in a summer, and only two at a time, and the other *hirundines* twice, the latter, who lay from four to six eggs, increase at an average five times as fast as the former.

But in nothing are swifts more singular than in their early retreat. They retire, as to the main body of them, by the tenth of August, and sometimes a few days sooner ; and every straggler invariably withdraws by the twentieth, while their congeners, all of them, stay till the beginning of October ; many of

them all through that month, and some occasionally to the beginning of November. This early retreat is mysterious and wonderful, since that time is often the sweetest season in the year. But, what is more extraordinary, they begin to retire still earlier in the most southerly parts of Andalusia, where they can be no ways influenced by any defect of heat; or, as one might suppose, defect of food. Are they regulated in their motions with us by a failure of food, or by a propensity to moulting, or by a disposition to rest after so rapid a life, or by what? This is one of those incidents in natural history that not only baffles our searches but almost eludes our guesses!

These *hirundines* never perch on trees or roofs, and so never congregate with their congeners. They are fearless while haunting their nesting places, and are not to be scared with a gun; and are often beaten down with poles and cudgels as they stoop to go under the eaves.

Swifts are no songsters, and have only one harsh screaming note; yet there are ears to which it is not displeasing, from an agreeable association of ideas, since that note never occurs but in the most lovely summer weather.

They never settle on the ground but through accident; and when down can hardly rise, on account of the shortness of their legs and the length of their wings: neither can they walk, but only crawl; but they have a strong grasp with their feet, by which they cling to walls. Their bodies being flat they can enter a very narrow crevice; and where they cannot pass on their bellies they will turn up edgewise.

The particular formation of the foot discriminates the swift from all British *hirundines*; and indeed from all other known birds, the *hirundo melba*, or great white-bellied swift of Gibraltar, excepted; for it is so disposed as to carry "*omnes quatuor digitos anticos*"

all its four toes forward; besides the least toe, which should be the back-toe, consists of one bone alone, and the other three only of two apiece. A construction most rare and peculiar, but nicely adapted to the purposes in which their feet are employed. This, and some peculiarities attending the nostrils and under mandible, have induced a discerning naturalist * to suppose that this species might constitute a *genus per se*.

In London a party of swifts frequents the Tower, playing and feeding over the river just below the bridge: others haunt some of the churches of the Borough next the fields, but do not venture, like the house-martin, into the close crowded part of the town.

The Swedes have bestowed a very pertinent name on this swallow, calling it *ring swala*, from the perpetual rings or circles that it takes round the scene of its nidification.

Swifts feed on *coleoptera*, or small beetles with hard cases over their wings, as well as on the softer insects; but it does not appear how they can procure gravel to grind their food, as swallows do, since they never settle on the ground.

On the fifth of July, 1775, I again untiled part of a roof over the nest of a swift. The dam sat in the nest; but so strongly was she affected by natural στοργὴ for her brood, which she supposed to be in danger, that, regardless of her own safety, she would not stir, but lay sullenly by them, permitting herself to be taken in hand. The squab young we brought down and placed on the grass-plot, where they tumbled about, and were as helpless as a new-born child. While we contemplated their naked bodies, their unwieldy disproportioned *abdomina*, and their heads, too heavy for their necks to support, we could not but wonder when we reflected that these shiftless beings in a little more

* John Antony Scopoli, of Carniola, M.D.

than a fortnight would be able to dash through the air almost with the inconceivable swiftness of a meteor ; and, perhaps, in their emigration must traverse vast continents and oceans as distant as the equator. So soon does nature advance small birds to their ἡλικὶα, or state of perfection ; while the progressive growth of men and large quadrupeds is slow and tedious !

I am, etc.

SELBORNE, *Sept.* 13, 1774

DEAR SIR—Perhaps it may be some amusement to you to hear at what times the different species of *hirundines* arrived this spring in three very distant counties of this kingdom. With us the swallow was seen first on April the 4th, the swift on April the 24th, the bank-martin on April the 12th, and the house-martin not till April the 30th. At South Zele, Devonshire, swallows did not arrive till April the 25th ; swifts, in plenty, on May the 1st ; and house-martins not till the middle of May. At Blackburn, in Lancashire, swifts were seen April the 28th, swallows April the 29th, house-martins May the 1st. Do these different dates, in such distant districts, prove anything for or against migration ?

GILBERT WHITE

GOSSAMER

SELBORNE, *June* 8, 1775

DEAR SIR—On September the 21st, 1741, being then on a visit, and intent on field-diversions, I rose before daybreak : when I came into the enclosures, I found the stubbles and clover-grounds matted all over with a thick coat of cobweb, in the meshes of which

a copious and heavy dew hung so plentifully that the whole face of the country seemed, as it were, covered with two or three setting-nets drawn one over another. When the dogs attempted to hunt, their eyes were so blinded and hoodwinked that they could not proceed, but were obliged to lie down and scrape the incumbrances from their faces with their fore-feet, so that, finding my sport interrupted, I returned home musing in my mind on the oddness of the occurrence.

As the morning advanced the sun became bright and warm, and the day turned out one of those most lovely ones which no season but the autumn produces ; cloudless, calm, serene, and worthy of the South of France itself.

About nine an appearance very unusual began to demand our attention, a shower of cobwebs falling from very elevated regions, and continuing, without any interruption, till the close of the day. These webs were not single filmy threads, floating in the air in all directions, but perfect flakes or rags ; some near an inch broad, and five or six long, which fell with a degree of velocity which showed they were considerably heavier than the atmosphere.

On every side as the observer turned his eyes might he behold a continual succession of fresh flakes falling into his sight, and twinkling like stars as they turned their sides towards the sun.

How far this wonderful shower extended would be difficult to say ; but we know that it reached Bradley, Selborne, and Alresford, three places which lie in a sort of a triangle, the shortest of whose sides is about eight miles in extent.

At the second of those places there was a gentleman (for whose veracity and intelligent turn we have the greatest veneration) who observed it the moment he got abroad ; but concluded that, as soon as he came

upon the hill above his house, where he took his morning rides, he should be higher than this meteor, which he imagined might have been blown, like thistle-down, from the common above: but, to his great astonishment, when he rode to the most elevated part of the down, 300 feet above his fields, he found the webs in appearance still as much above him as before; still descending into sight in a constant succession, and twinkling in the sun, so as to draw the attention of the most incurious.

Neither before nor after was any such fall observed; but on this day the flakes hung in the trees and hedges so thick, that a diligent person sent out might have gathered baskets full.

The remark that I shall make on these cobweb-like appearances, called gossamer, is, that, strange and superstitious as the notions about them were formerly, nobody in these days doubts but that they are the real production of small spiders, which swarm in the fields in fine weather in autumn, and have a power of shooting out webs from their tails so as to render themselves buoyant, and lighter than air. But why these apterous insects should that day take such a wonderful aerial excursion, and why their webs should at once become so gross and material as to be considerably more weighty than air, and to descend with precipitation, is a matter beyond my skill. If I might be allowed to hazard a supposition, I should imagine that those filmy threads, when first shot, might be entangled in the rising dew, and so drawn up, spiders and all, by a brisk evaporation into the region where clouds are formed: and if the spiders have a power of coiling and thickening their webs in the air, then, when they were become heavier than the air, they must fall.

Every day in fine weather, in autumn chiefly, do I see those spiders shooting out their webs and mounting aloft: they will go off from your finger if you

will take them into your hand. Last summer one alighted on my book as I was reading in the parlour ; and, running to the top of the page, and shooting out a web, took its departure from thence. But what I most wondered at, was that it went off with considerable velocity in a place where no air was stirring ; and I am sure that I did not assist it with my breath. So that these little crawlers seem to have, while mounting, some locomotive power without the use of wings, and to move in the air, faster than the air itself.

GILBERT WHITE

CRICKETS

SELBORNE

THERE is a steep abrupt pasture field interspersed with furze close to the back of this village, well known Field by the name of the Short Lithe, consisting of a rocky House dry soil, and inclining to the afternoon sun. This Mole spot abounds with the *gryllus campestris*, or field-cricket ; which, though frequent in these parts, is by no means a common insect in many other counties.

As their cheerful summer cry cannot but draw the attention of a naturalist, I have often gone down to examine the economy of these *grylli*, and study their mode of life ; but they are so shy and cautious that it is no easy matter to get a sight of them ; for, feeling a person's footsteps as he advances, they stop short in the midst of their song, and retire backward nimbly into their burrows, where they lurk till all suspicion of danger is over.

At first we attempted to dig them out with a spade, but without any great success ; for either we could not get to the bottom of the hole, which often terminated under a great stone ; or else, in breaking up the ground, we inadvertently squeezed the poor insect to

death. Out of one so bruised we took a multitude of eggs, which were long and narrow, of a yellow colour, and covered with a very tough skin. By this accident we learned to distinguish the male from the female ; the former of which is shining black, with a golden stripe across his shoulders ; the latter is more dusky, more capacious about the abdomen, and carries a long sword-shaped weapon at her tail, which probably is the instrument with which she deposits her eggs in crannies and safe receptacles.

Where violent methods will not avail, more gentle means will often succeed ; and so it proved in the present case ; for, though a spade be too boisterous and rough an implement, a pliant stalk of grass, gently insinuated into the caverns, will probe their windings to the bottom, and quickly bring out the inhabitant ; and thus the humane inquirer may gratify his curiosity without injuring the object of it. It is remarkable that, though these insects are furnished with long legs behind, and brawny thighs for leaping, like grasshoppers ; yet when driven from their holes they show no activity, but crawl along in a shiftless manner, so as easily to be taken : and again, though provided with a curious apparatus of wings, yet they never exert them when there seems to be the greatest occasion. The males only make that shrilling noise perhaps out of rivalry and emulation, as is the case with many animals which exert some sprightly note during their breeding time : it is raised by a brisk friction of one wing against the other. When the males meet they will fight fiercely, as I found by some which I put into the crevices of a dry stone wall, where I should have been glad to have made them settle. For though they seemed distressed by being taken out of their knowledge, yet the first that got possession of the chinks would seize upon any that were obtruded upon them with a vast row of serrated fangs. With their

strong jaws, toothed like the shears of a lobster's claws, they perforate and round their curious regular cells, having no fore-claws to dig, like the mole-cricket. When taken in hand I could not but wonder that they never offered to defend themselves, though armed with such formidable weapons. Of such herbs as grow before the mouths of their burrows they eat indiscriminately ; and never, in the day-time, seem to stir more than two or three inches from home. Sitting in the entrance of their caverns they chirp all night as well as day from the middle of the month of May to the middle of July ; and in hot weather, when they are most vigorous, they make the hills echo ; and, in the stiller hours of darkness, may be heard to a considerable distance. In the beginning of the season, their notes are more faint and inward ; but become louder as the summer advances, and so die away again by degrees.

Sounds do not always give us pleasure according to their sweetness and melody ; nor do harsh sounds always displease. We are more apt to be captivated or disgusted with the associations which they promote, than with the notes themselves. Thus the shrilling of the field-cricket, though sharp and stridulous, yet marvellously delights some hearers, filling their minds with a train of summer ideas of everything that is rural, verdurous, and joyous.

About the tenth of March the crickets appear at the mouths of their cells, which they then open and bore, and shape very elegantly. All that ever I have seen at that season were in their pupa state, and had only the rudiments of wings, lying under a skin or coat, which must be cast before the insect can arrive at its perfect state ; * from whence I should suppose that the old ones of last year do not always survive the winter. In

* We have observed that they cast these skins in April, which are then seen lying at the mouths of their holes.

August their holes begin to be obliterated, and the insects are seen no more till spring.

Not many summers ago I endeavoured to transplant a colony to the terrace in my garden, by boring deep holes in the sloping turf. The new inhabitants stayed some time, and fed and sung ; but wandered away by degrees, and were heard at a farther distance every morning ; so that it appears that on this emergency they made use of their wings in attempting to return to the spot from which they were taken.

One of these crickets, when confined in a paper cage and set in the sun, and supplied with plants moistened with water, will feed and thrive, and become so merry and loud as to be irksome in the same room where a person is sitting : if the plants are not wetted it will die.

> " Far from all resort of mirth
> Save the cricket on the hearth."
>
> MILTON'S *Il Penseroso*

SELBORNE

DEAR SIR—While many other insects must be sought after in fields and woods, and waters, the *gryllus domesticus*, or house-cricket, resides altogether within our dwellings, intruding itself upon our notice whether we will or no. This species delights in new-built houses, being, like the spider, pleased with the moisture of the walls ; and besides, the softness of the mortar enables them to burrow and mine between the joints of the bricks or stones, and to open communications from one room to another. They are particularly fond of kitchens and baker's ovens, on account of their perpetual warmth.

Tender insects that live abroad either enjoy only the short period of one summer, or else doze away the

cold uncomfortable months in profound slumbers ; but these, residing as it were in a torrid zone, are always alert and merry : a good Christmas fire is to them like the heats of the dog-days. Though they are frequently heard by day, yet is their natural time of motion only in the night. As soon as it grows dusk the chirping increases, and they come running forth, and are from the size of a flea to that of their full stature. As one should suppose, from the burning atmosphere which they inhabit, they are a thirsty race, and show a great propensity for liquids, being found frequently drowned in pans of water, milk, broth, or the like. Whatever is moist they affect ; and therefore often gnaw holes in wet woollen stockings and aprons that are hung to the fire : they are the housewife's barometer, foretelling her when it will rain ; and a prognostic sometimes, she thinks, of ill or good luck ; of the death of a near relation, or the approach of an absent lover. By being the constant companions of her solitary hours they naturally become the objects of her superstition. These crickets are not only very thirsty, but very voracious ; for they will eat the scummings of pots, and yeast, salt, and crumbs of bread ; and any kitchen offal or sweepings. In the summer we have observed them to fly, when it became dusk, out of the windows, and over the neighbouring roofs. This feat of activity accounts for the sudden manner in which they often leave their haunts, as it does for the method by which they come to houses where they were not known before. It is remarkable that many sorts of insects seem never to use their wings but when they have a mind to shift their quarters and settle new colonies. When in the air they move "*volatu undoso,*" in waves or curves, like woodpeckers, opening and shutting their wings at every stroke, and so are always rising or sinking.

When they increase to a great degree, as they did

once in the house where I am now writing, they become noisome pests, flying into the candles, and dashing into people's faces ; but may be blasted and destroyed by gunpowder discharged into their crevices and crannies. In families, at such times, they are, like Pharaoh's plague of frogs,—" in their bedchambers, and upon their beds, and in their ovens, and in their kneading-troughs." Their shrilling noise is occasioned by the brisk attrition of their wings. Cats catch hearth crickets, and, playing with them as they do with mice, devour them. Crickets may be destroyed, like wasps, by phials half filled with beer, or any liquid, and set in their haunts ; for, being always eager to drink, they will crowd in till the bottles are full.

SELBORNE

How diversified are the modes of life not only of incongruous but even of congenerous animals ; and yet their specific distinctions are not more various than their propensities. Thus, while the field-cricket delights in sunny dry banks, and the house-cricket rejoices amidst the glowing heat of the kitchen hearth or oven, the *gryllus gryllo talpa* (the mole-cricket) haunts moist meadows, and frequents the sides of ponds and banks of streams, performing all its functions in a swampy wet soil. With a pair of fore-feet, curiously adapted to the purpose, it burrows and works under ground like the mole, raising a ridge as it proceeds, but seldom throwing up hillocks.

As mole-crickets often infest gardens by the sides of canals, they are unwelcome guests to the gardener, raising up ridges in their subterraneous progress, and rendering the walks unsightly. If they take to the kitchen quarters, they occasion great damage among the plants and roots, by destroying whole beds of cabbages, young legumes, and flowers. When dug

out they seem very slow and helpless, and make no use of their wings by day ; but at night they come abroad, and make long excursions, as I have been convinced by finding stragglers, in a morning, in improbable places. In fine weather, about the middle of April, and just at the close of day, they begin to solace themselves with a low, dull, jarring note, continued for a long time without interruption, and not unlike the chattering of the fern-owl, or goat-sucker, but more inward.

About the beginning of May they lay their eggs, as I was once an eye-witness : for a gardener at a house, where I was on a visit, happening to be mowing, on the 6th of that month, by the side of a canal, his scythe struck too deep, pared off a large piece of turf, and laid open to view a curious scene of domestic economy.

There were many caverns and winding passages leading to a kind of chamber, neatly smoothed and rounded, and about the size of a moderate snuff-box. Within this secret nursery were deposited near an hundred eggs of a dirty yellow colour, and enveloped in a tough skin, but too lately excluded to contain any rudiments of young, being full of a viscous substance. The eggs lay but shallow, and within the influence of the sun, just under a little heap of fresh-moved mould, like that which is raised by ants.

When mole-crickets fly they move "*cursu undoso*," rising and falling in curves, like the other species mentioned before. In different parts of this kingdom people call them fen-crickets, churr-worms, and eve-churrs, all very apposite names.

Anatomists, who have examined the intestines of these insects, astonish me with their accounts ; for they say that, from the structure, position, and number of their stomachs, or maws, there seems to be good

reason to suppose that this and the two former species ruminate or chew the cud like many quadrupeds !

GILBERT WHITE

THE PAGEANT OF SUMMER

GREEN rushes, long and thick, standing up above the edge of the ditch, told the hour of the year as distinctly as the shadow on the dial the hour of the day. Green and thick and sappy to the touch, they felt like summer, soft and elastic, as if full of life, mere rushes though they were. On the fingers they left a green scent ; rushes have a separate scent of green, so, too, have ferns, very different to that of grass or leaves. Rising from brown sheaths, the tall stems enlarged a little in the middle, like classical columns, and heavy with their sap and freshness, leaned against the hawthorn sprays. From the earth they had drawn its moisture, and made the ditch dry ; some of the sweetness of the air had entered into their fibres, and the rushes—the common rushes—were full of beautiful summer. The white pollen of early grasses growing on the edge was dusted from them each time the hawthorn boughs were shaken by a thrush. These lower sprays came down in among the grass, and leaves and grass-blades touched. Smooth round stems of angelica, big as a gun-barrel, hollow and strong, stood on the slope of the mound, their tiers of well-balanced branches rising like those of a tree. Such a sturdy growth pushed back the ranks of hedge parsley in full white flower, which blocked every avenue and winding bird's-path of the bank. But the "gix," or wild parsnip, reached already high above both, and would rear its fluted stalk, joint on joint, till it could face a man. Trees they were to the lesser birds, not even

bending if perched on ; but though so stout, the birds did not place their nests on or against them. Something in the odour of these umbelliferous plants, perhaps, is not quite liked ; if brushed or bruised they give out a bitter greenish scent. Under their cover, well shaded and hidden, birds build, but not against or on the stems, though they will affix their nests to much less certain supports. With the grasses that overhung the edge, with the rushes in the ditch itself, and these great plants on the mound, the whole hedge was wrapped and thickened. No cunning of glance could see through it ; it would have needed a ladder to help any one look over.

It was between the May and the June roses. The May-bloom had fallen, and among the hawthorn boughs were the little green bunches that would feed the redwings in autumn. High up the briars had climbed, straight and towering while there was a thorn, or an ash sapling, or a yellow-green willow to uphold them, and then curving over towards the meadow. The buds were on them, but not yet open ; it was between the may and the rose.

As the wind, wandering over the sea, takes from each wave an invisible portion, and brings to those on shore the ethereal essence of ocean, so the air lingering among the woods and hedges—green waves and billows—became full of fine atoms of summer. Swept from notched hawthorn leaves, broad-topped oak-leaves, narrow ash sprays and oval willows ; from vast elm cliffs and sharp-taloned brambles under ; brushed from the waving grasses and stiffening corn, the dust of the sunshine was borne along and breathed. Steeped in flower and pollen to the music of bees and birds, the stream of the atmosphere became a living thing. It was life to breathe it, for the air itself was life. The strength of the earth went up through the leaves into the wind. Fed thus on the food of the

Immortals, the heart opened to the width and depth of the summer—to the broad horizon afar, down to the minutest creature in the grass, up to the highest swallow. Winter shows us Matter in its dead form, like the Primary rocks, like granite and basalt—clear but cold and frozen crystal. Summer shows us Matter changing into life, sap rising from the earth through a million tubes, the alchemic power of light entering the solid oak ; and see ! it bursts forth in countless leaves. Living things leap in the grass, living things drift upon the air, living things are coming forth to breathe in every hawthorn bush. No longer does the immense weight of Matter—the dead, the crystallised—press ponderously on the thinking mind. The whole office of Matter is to feed life—to feed the green rushes, and the roses that are about to be ; to feed the swallows above, and us that wander beneath them. So much greater is this green and common rush than all the Alps.

Fanning so swiftly, the wasp's wings are but just visible as he passes ; did he pause, the light would be apparent through their texture. On the wings of the dragon-fly as he hovers an instant before he darts there is a prismatic gleam. These wing textures are even more delicate than the minute filaments on a swallow's quill, more delicate than the pollen of a flower. They are formed of matter indeed, but how exquisitely it is resolved into the means and organs of life ! Though not often consciously recognised, perhaps this is the great pleasure of summer, to watch the earth, the dead particles, resolving themselves into the living case of life, to see the seed-leaf push aside the clod and become by degrees the perfumed flower. From the tiny mottled egg come the wings that by-and-by shall pass the immense sea. It is in this marvellous transformation of clods and cold matter into living things that the joy and the hope of summer

reside. Every blade of grass, each leaf, each separate floret and petal, is an inscription speaking of hope. Consider the grasses and the oaks, the swallows, the sweet blue butterfly—they are one and all a sign and token showing before our eyes earth made into life. So that my hope becomes as broad as the horizon afar, reiterated by every leaf, sung on every bough, reflected in the gleam of every flower. There is so much for us yet to come, so much to be gathered, and enjoyed. Not for you and me, now, but for our race, who will ultimately use this magical secret for their happiness. Earth holds secrets enough to give them the life of the fabled Immortals. My heart is fixed firm and stable in the belief that ultimately the sunshine and the summer, the flowers and the azure sky, shall become, as it were, interwoven into man's existence. He shall take from all their beauty and enjoy their glory. Hence it is that a flower is to me so much more than stalk and petals. When I look in the glass I see that every line in my face means pessimism ; but in spite of my face—that is my experience—I remain an optimist. Time with an unsteady hand has etched thin crooked lines, and, deepening the hollows, has cast the original expression into shadow. Pain and sorrow flow over us with little ceasing, as the sea-hoofs beat on the beach. Let us not look at ourselves but onwards, and take strength from the leaf and the signs of the field. He is indeed despicable who cannot look onwards to the ideal life of man. Not to do so is to deny our birthright of mind.

The long grass flowing towards the hedge has reared in a wave against it. Along the hedge it is higher and greener, and rustles into the very bushes. There is a mark only now where the footpath was ; it passed close to the hedge, but its place is traceable only as a groove in the sorrel and seed-tops. Though it has quite filled the path, the grass there cannot send its

tops so high ; it has left a winding crease. By the hedge here stands a moss-grown willow, and its slender branches extend over the sward. Beyond it is an oak, just apart from the bushes ; then the ground gently rises, and an ancient pollard ash, hollow and black inside, guards an open gateway like a low tower. The different tone of green shows that the hedge is there of nut-trees ; but one great hawthorn spreads out in a semicircle, roofing the grass which is yet more verdant in the still pool (as it were) under it. Next a corner, more oaks, and a chestnut in bloom. Returning to this spot an old apple tree stands right out in the meadow like an island. There seemed just now the tiniest twinkle of movement by the rushes, but it was lost among the hedge parsley. Among the grey leaves of the willow there is another flit of motion ; and visible now against the sky there is a little brown bird, not to be distinguished at the moment from the many other little brown birds that are known to be about. He got up into the willow from the hedge parsley somehow, without being seen to climb or fly. Suddenly he crosses to the tops of the hawthorn and immediately flings himself up into the air a yard or two, his wings and ruffled crest making a ragged outline ; jerk, jerk, jerk, as if it were with the utmost difficulty he could keep even at that height. He scolds, and twitters, and chirps, and all at once sinks like a stone into the hedge and out of sight as a stone into a pond. It is a whitethroat ; his nest is deep in the parsley and nettles. Presently he will go out to the island apple tree and back again in a minute or two ; the pair of them are so fond of each other's affectionate company they cannot remain apart.

Watching the line of the hedge, about every two minutes, either near at hand or yonder a bird darts out just at the level of the grass, hovers a second with labouring wings, and returns as swiftly to the cover.

Sometimes it is a fly-catcher, sometimes a greenfinch, or chaffinch, now and then a robin, in one place a shrike, perhaps another is a redstart. They are fly-fishing all of them, seizing insects from the sorrel tips and grass, as the kingfisher takes a roach from the water. A blackbird slips up into the oak and a dove descends in the corner by the chestnut tree. But these are not visible together, only one at a time and with intervals. The larger part of the life of the hedge is out of sight. All the thrush-fledglings, the young blackbirds and finches are hidden, most of them on the mound among the ivy, and parsley, and rough grasses, protected too by a roof of brambles. The nests that still have eggs are not, like the nests of the early days of April, easily found ; they are deep down in the tangled herbage by the shore of the ditch, or far inside the thorny thickets which then looked mere bushes, and are now so broad. Landrails are running in the grass concealed as a man would be in a wood ; they have nests and eggs on the ground for which you may search in vain till the mowers come.

Up in the corner a fragment of white fur and marks of scratching show where a doe has been preparing for a litter. Some well-trodden runs lead from mound to mound ; they are sandy near the hedge where the particles have been carried out adhering to the rabbits' feet and fur. A crow rises lazily from the upper end of the field, and perches in the chestnut. His presence, too, was unsuspected. He is there by far too frequently. At this season the crows are always in the mowing-grass, searching about, stalking in winding tracks from furrow to furrow, picking up an egg here and a foolish fledgling that has wandered from the mound yonder. Very likely there may be a moorhen or two slipping about under cover of the long grass ; thus hidden, they can leave the shelter of the flags and wander a distance from the brook.

So that beneath the surface of the grass and under the screen of the leaves there are ten times more birds than are seen.

Besides the singing and calling, there is a peculiar sound which is only heard in summer. Waiting quietly to discover what birds are about, I became aware of a sound in the very air. It is not the midsummer hum which will soon be heard over the heated hay in the valley and over the cooler hills alike. It is not enough to be called a hum, and does but just tremble at the extreme edge of hearing. If the branches wave and rustle they overbear it ; the buzz of a passing bee is so much louder it overcomes all of it that is in the whole field. I cannot define it, except by calling the hours of winter to mind—they are silent ; you hear a branch crack or creak as it rubs another in the wood, you hear the hoar-frost crunch on the grass beneath your feet, but the air is without sound in itself. The sound of summer is everywhere—in the passing breeze, in the hedge, in the broad-branching trees, in the grass as it swings ; all the myriad particles that together make the summer are in motion. The sap moves in the trees, the pollen is pushed out from grass and flower, and yet again these acres and acres of leaves and square miles of grass blades—for they would cover acres and square miles if reckoned edge to edge—are drawing their strength from the atmosphere. Exceedingly minute as these vibrations must be, their numbers perhaps may give them a volume almost reaching in the aggregate to the power of the ear. Besides the quivering leaf, the swinging grass, the fluttering bird's wing, and the thousand oval membranes which innumerable insects whirl about, a faint resonance seems to come from the very earth itself. The fervour of the sunbeams descending in a tidal flood rings on the strung harp of earth. It is this exquisite undertone, heard and yet

unheard, which brings the mind into sweet accordance with the wonderful instrument of nature.

By the apple tree there is a low bank, where the grass is less tall and admits the heat direct to the ground ; here there are blue flowers—bluer than the wings of my favourite butterflies—with white centres —the lovely bird's-eyes, or veronica. The violet and cowslip, bluebell and rose, are known to thousands ; the veronica is overlooked. The ploughboys know it, and the wayside children, the mower and those who linger in fields, but few else. Brightly blue and surrounded by greenest grass, imbedded in and all the more blue for the shadow of the grass, these growing butterflies' wings draw to themselves the sun. From this island I looked down into the depth of the grasses. Red sorrel spires—deep drinkers of reddest sun wine—stand the boldest, and in their numbers threaten the buttercups. To these in the distance they give the gipsy-gold tint—the reflection of fire on plates of the precious metal. It will show even on a ring by firelight ; blood in the gold, they say. Gather the open marguerite daisies, and they seem large—so wide a disc, such fingers of rays ; but in the grass their size is toned by so much green. Clover heads of honey lurk in the bunches and by the hidden footpath. Like clubs from Polynesia the tips of the grasses are varied in shape : some tend to a point—the foxtails—some are hard and cylindrical ; others, avoiding the club shape, put forth the slenderest branches with fruit of seed at the ends, which tremble as the air goes by. Their stalks are ripening and becoming of the colour of hay while yet the long blades remain green.

Each kind is repeated a hundred times, the foxtails are succeeded by foxtails, the narrow blades by narrow blades, but never become monotonous ; sorrel stands by sorrel, daisy flowers by daisy. This bed of veronica at the foot of the ancient apple has a whole handful

of flowers, and yet they do not weary the eye. Oak follows oak and elm ranks with elm, but the woodlands are pleasant ; however many times reduplicated, their beauty only increases. So, too, the summer days ; the sun rises on the same grasses and green hedges, there is the same blue sky, but did we ever have enough of them ? No, not in a hundred years ! There seems always a depth, somewhere, unexplored, a thicket that has not been seen through, a corner full of ferns, a quaint old hollow tree, which may give us something. Bees go by me as I stand under the apple, but they pass on for the most part bound on a long journey, across to the clover fields or up to the thyme lands ; only a few go down into the mowing-grass. The hive bees are the most impatient of insects ; they cannot bear to entangle their wings beating against grasses or boughs. Not one will enter a hedge. They like an open and level surface, places cropped by sheep, the sward by the roadside, fields of clover, where the flower is not deep under grass.

II

It is the patient humble-bee that goes down into the forest of the mowing-grass. If entangled, the humble-bee climbs up a sorrel stem and takes wing, without any sign of annoyance. His broad back with tawny bar buoyantly glides over the golden buttercups. He hums to himself as he goes, so happy is he. He knows no skep, no cunning work in glass receives his labour, no artificial saccharine aids him when the beams of the sun are cold, there is no step to his house that he may alight in comfort ; the way is not made clear for him that he may start straight for the flowers, nor are any sown for him. He has no shelter if the storm descends suddenly ; he has no dome of twisted

straw well thatched and tiled to retreat to. The butcher-bird, with a beak like a crooked iron nail, drives him to the ground, and leaves him pierced with a thorn ; but no hail of shot revenges his tortures. The grass stiffens at nightfall (in autumn), and he must creep where he may, if possibly he may escape the frost. No one cares for the humble-bee. But down to the flowering nettle in the mossy-sided ditch, up into the tall elm, winding in and out and round the branched buttercups, along the banks of the brook, far inside the deepest wood, away he wanders and despises nothing. His nest is under the rough grasses and the mosses of the mound, a mere tunnel beneath the fibres and matted surface. The hawthorn overhangs it, the fern grows by, red mice rustle past.

It thunders, and the great oak trembles ; the heavy rain drops through the treble roof of oak and hawthorn and fern. Under the arched branches the lightning plays along, swiftly to and fro, or seems to, like the swish of a whip, a yellowish-red against the green ; a boom ! a crackle as if a tree fell from the sky. The thick grasses are bowed, the white florets of the wild parsley are beaten down, the rain hurls itself, and suddenly a fierce blast tears the green oak leaves and whirls them out into the fields ; but the humble-bee's home, under moss and matted fibres, remains uninjured. His house at the root of the king of trees, like a cave in the rock, is safe. The storm passes and the sun comes out, the air is the sweeter and the richer for the rain, like verses with a rhyme ; there will be more honey in the flowers. Humble he is, but wild ; always in the field, the wood ; always by the banks and thickets ; always wild and humming to his flowers. Therefore I like the humble-bee, being, at heart at least, for ever roaming among the woodlands and the hills and by the brooks. In such quick summer storms the lightning gives the impression of being far

more dangerous than the zigzag paths traced on the autumn sky. The electric cloud seems almost level with the ground and the livid flame to rush to and fro beneath the boughs as the little bats do in the evening.

Caught by such a cloud, I have stayed under thick larches at the edge of plantations. They are no shelter, but conceal one perfectly. The wood-pigeons come home to their nest trees ; in larches they seem to have permanent nests, almost like rooks. Kestrels, too, come home to the wood. Pheasants crow, but not from fear—from defiance ; in fear they scream. The boom startles them, and they instantly defy the sky. The rabbits quietly feed on out in the field between the thistles and rushes that so often grow in woodside pastures, quietly hopping to their favourite places, utterly heedless how heavy the echoes may be in the hollows of the wooded hills. Till the rain comes they take no heed whatever, but then make for shelter. Blackbirds often make a good deal of noise ; but the soft turtle-doves coo gently, let the lightning be as savage as it will. Nothing has the least fear. Man alone, more senseless than a pigeon, put a god in vapour ; and to this day, though the printing press has set a foot on every threshold, numbers bow the knee when they hear the roar the timid dove does not heed. So trustful are the doves, the squirrels, the birds of the branches, and the creatures of the field. Under their tuition let us rid ourselves of mental terrors, and face death itself as calmly as they do the livid lightning ; so trustful and so content with their fate, resting in themselves and unappalled. If but by reason and will I could reach the godlike calm and courage of what we so thoughtlessly call the timid turtle-dove, I should lead a nearly perfect life.

The bark of the ancient apple tree under which I have been standing is shrunken like iron which has

been heated and let cool round the rim of a wheel. For a hundred years the horses have rubbed against it while feeding in the aftermath. The scales of the bark are gone or smoothed down and level, so that insects have no hiding-place. There are no crevices for them, the horsehairs that were caught anywhere have been carried away by birds for their nests. The trunk is smooth and columnar, hard as iron. A hundred times the mowing-grass has grown up around it, the birds have built their nests, the butterflies fluttered by, and the acorns dropped from the oaks. It is a long, long time, counted by artificial hours or by the seasons, but it is longer still in another way. The greenfinch in the hawthorn yonder has been there since I came out, and all the time has been happily talking to his love. He has left the hawthorn indeed, but only for a minute or two, to fetch a few seeds, and comes back each time more full of song-talk than ever. He notes no slow movement of the oak's shadow on the grass ; it is nothing to him and his lady dear that the sun, as seen from his nest, is crossing from one great bough of the oak to another. The dew even in the deepest and most tangled grass has long since been dried, and some of the flowers that close at noon will shortly fold their petals. The morning airs, which breathe so sweetly, come less and less frequently as the heat increases. Vanishing from the sky, the last fragments of cloud have left an untarnished azure. Many times the bees have returned to their hives, and thus the index of the day advances. It is nothing to the greenfinches ; all their thoughts are in their song-talk. The sunny moment is to them all in all. So deeply are they rapt in it that they do not know whether it is a moment or a year. There is no clock for feeling, for joy, for love.

And with all their motions and stepping from bough to bough, they are not restless ; they have so much time,

you see. So, too, the whitethroat in the wild parsley; so, too, the thrush that just now peered out and partly fluttered his wings as he stood to look. A butterfly comes and stays on a leaf—a leaf much warmed by the sun—and shuts his wings. In a minute he opens them, shuts them again, half wheels round, and by-and-by—just when he chooses, and not before—floats away. The flowers open, and remain open for hours, to the sun. Hastelessness is the only word one can make up to describe it; there is much rest, but no haste. Each moment, as with the greenfinches, is so full of life that it seems so long and so sufficient in itself. Not only the days, but life itself lengthens in summer. I would spread abroad my arms and gather more of it to me, could I do so.

All the procession of living and growing things passes. The grass stands up taller and still taller, the sheaths open, and the stalk arises, the pollen clings till the breeze sweeps it. The bees rush past, and the resolute wasps; the humble-bees, whose weight swings them along. About the oaks and maples the brown chafers swarm, and the fern-owls at dusk, and the blackbirds and jays by day, cannot reduce their legions while they last. Yellow butterflies, and white, broad red admirals, and sweet blues; think of the kingdom of flowers which is theirs! Heavy moths burring at the edge of the copse; green, and red, and gold flies: gnats, like smoke, around the tree-tops; midges so thick over the brook, as if you could haul a netful; tiny leaping creatures in the grass; bronze beetles across the path; blue dragon-flies pondering on cool leaves of water-plantain. Blue jays flitting, a magpie drooping across from elm to elm; young rooks that have escaped the hostile shot blundering up into the branches; missel thrushes leading their fledglings, already strong on the wing, from field to field. An egg here on the sward dropped by a star-

ling ; a red ladybird creeping, tortoise-like, up a green fern frond. Finches undulating through the air, shooting themselves with closed wings, and linnets happy with their young.

Golden dandelion discs—gold and orange—of a hue more beautiful, I think, than the higher and more visible buttercup. A blackbird, gleaming, so black is he, splashing in the runlet of water across the gateway. A ruddy kingfisher swiftly drawing himself, as you might draw a stroke with a pencil, over the surface of the yellow buttercups, and away above the hedge. Hart's-tongue fern, thick with green, so green as to be thick with its colour, deep in the ditch under the shady hazel boughs. White meadow-sweet lifting its tiny florets, and black-flowered sedges. You must push through the reed grass to find the sword-flags ; the stout willow-herbs will not be trampled down, but resist the foot like underwood. Pink lychnis flowers behind the withy stoles, and little black moorhens swim away, as you gather it, after their mother, who has dived under the water-grass, and broken the smooth surface of the duckweed. Yellow loosestrife is rising, thick comfrey stands at the very edge ; the sandpipers run where the shore is free from bushes. Back by the underwood the prickly and repellent brambles will presently present us with fruit. For the squirrels the nuts are forming, green beechmast is there—green wedges under the spray ; up in the oaks the small knots, like bark rolled up in a dot, will be acorns. Purple vetches along the mounds, yellow lotus where the grass is shorter, and orchis succeeds to orchis. As I write them, so these things come—not set in graduation, but like the broadcast flowers in the mowing-grass.

Now follows the gorse, and the pink rest-harrow, and the sweet lady's-bedstraw, set as it were in the midst of a little thorn-bush. The broad repetition of

the yellow clover is not to be written ; acre upon acre, and not one spot of green, as if all the green had been planed away, leaving only the flowers to which the bees come by the thousand from far and near. But one white campion stands in the midst of the lake of yellow. The field is scented as though a hundred hives of honey had been emptied on it. Along the mound by it the bluebells are seeding, the hedge has been cut and the ground is strewn with twigs. Among those seeding bluebells and dry twigs and mosses I think a titlark has his nest, as he stays all day there and in the oak over. The pale clear yellow of charlock, sharp and clear, promises the finches bushels of seed for their young. Under the scarlet of the poppies the larks run, and then for change of colour soar into the blue. Creamy honeysuckle on the hedge around the cornfield, buds of wild rose everywhere, but no sweet petal yet. Yonder, where the wheat can climb no higher up the slope, are the purple heath-bells, thyme, and flitting stonechats.

The lone barn shut off by acres of barley is noisy with sparrows. It is their city, and there is a nest in every crevice, almost under every tile. Sometimes the partridges run between the ricks, and when the bats come out of the roof, leverets play in the waggon-track. At even a fern-owl beats by, passing close to the eaves whence the moths issue. On the narrow waggon-track which descends along a coombe and is worn in chalk, the heat pours down by day as if an invisible lens in the atmosphere focussed the sun's rays. Strong woody knapweed endures it, so does toadflax and pale blue scabious, and wild mignonette. The very sun of Spain burns and burns and ripens the wheat on the edge of the coombe, and will only let the spring moisten a yard or two around it ; but there a few rushes have sprung, and in the water itself brooklime with blue flowers grows so thickly that nothing but a

bird could find space to drink. So down again from this sun of Spain to woody coverts where the wild hops are blocking every avenue, and green-flowered bryony would fain climb to the trees ; where grey-flecked ivy winds spirally about the red rugged bark of pines, where burdocks fight for the footpath, and teazle-heads look over the low hedges. Brake-fern rises five feet high ; in some way woodpeckers are associated with brake, and there seem more of them where it flourishes. If you count the depth and strength of its roots in the loamy sand, add the thickness of its flattened stem, and the width of its branching fronds, you may say that it comes near to be a little tree. Beneath where the ponds are bushy mare's-tails grow, and on the moist banks jointed pewterwort ; some of the broad bronze leaves of water-weeds seem to try and conquer the pond and cover it so firmly that a wagtail may run on them. A white butterfly follows along the waggon-road, the pheasants slip away as quietly as the butterfly flies, but a jay screeches loudly and flutters in high rage to see us. Under an ancient garden wall among matted bines of trumpet convolvulus, there is a hedge-sparrow's nest overhung with ivy on which even now the last black berries cling.

There are minute white flowers on the top of the wall, out of reach, and lichen grows against it dried by the sun till it looks ready to crumble. By the gateway grows a thick bunch of meadow geranium, soon to flower ; over the gate is the dusty highway road, quiet but dusty, dotted with the innumerable footmarks of a flock of sheep that has passed. The sound of their bleating still comes back, and the bees driven up by their feet have hardly had time to settle again on the white clover beginning to flower on the short roadside sward. All the hawthorn leaves and briar and bramble, the honeysuckle, too, is gritty with the

dust that has been scattered upon it. But see—can it be? Stretch a hand high, quick, and reach it down; the first, the sweetest, the dearest rose of June. Not yet expected, for the time is between the may and the roses, least of all here in the hot and dusty highway; but it is found—the first rose of June.

Straight go the white petals to the heart; straight the mind's glance goes back to how many other pageants of summer in old times! When perchance the sunny days were even more sunny; when the stilly oaks were full of mystery, lurking like the Druid's mistletoe in the midst of their mighty branches. A glamour in the heart came back to it again from every flower; as the sunshine was reflected from them so the feeling in the heart returned tenfold. To the dreamy summer haze love gave a deep enchantment, the colours were fairer, the blue more lovely in the lucid sky. Each leaf finer, and the gross earth enamelled beneath the feet. A sweet breath on the air, a soft warm hand in the touch of the sunshine, a glance in the gleam of the rippled waters, a whisper in the dance of the shadows. The ethereal haze lifted the heavy oaks and they were buoyant on the mead, the rugged bark was chastened and no longer rough, each slender flower beneath them again refined. There was a presence everywhere though unseen, on the open hills, and not shut out under the dark pines. Dear were the June roses then because for another gathered. Yet even dearer now with so many years as it were upon the petals; all the days that have been before, all the heart-throbs, all our hopes lie in this opened bud. Let not the eyes grow dim, look not back but forward; the soul must uphold itself like the sun. Let us labour to make the heart grow larger as we become older, as the spreading oak gives more shelter. That we could but take to the soul some of the greatness and the beauty of the summer!

Still the pageant moves. The song-talk of the finches rises and sinks like the tinkle of a waterfall. The greenfinches have been by me all the while. A bullfinch pipes now and then further up the hedge where the brambles and thorns are thickest. Boldest of birds to look at, he is always in hiding. The shrill tone of a goldfinch came just now from the ash branches, but he has gone on. Every four or five minutes a chaffinch sings close by, and another fills the interval near the gateway. There are linnets somewhere, but I cannot from the old apple tree fix their exact place. Thrushes have sung and ceased; they will begin again in ten minutes. The blackbirds do not cease; the note uttered by a blackbird in the oak yonder before it can drop is taken up by a second near the top of the field, and ere it falls is caught by a third on the left-hand side. From one of the topmost boughs of an elm there fell the song of a willow warbler for awhile; one of the least of birds, he often seeks the highest branches of the highest tree.

A yellowhammer has just flown from a bare branch in the gateway, where he has been perched and singing a full hour. Presently he will commence again, and as the sun declines will sing him to the horizon, and then again sing till nearly dusk. The yellowhammer is almost the longest of all the singers; he sits and sits and has no inclination to move. In the spring he sings, in the summer he sings, and he continues when the last sheaves are being carried from the wheat field. The redstart yonder has given forth a few notes, the whitethroat flings himself into the air at short intervals and chatters, the shrike calls sharp and determined, faint but shrill calls descend from the swifts in the air. These descend, but the twittering notes of the swallows do not reach so far—they are too high to-day. A cuckoo has called by the brook, and now fainter from a greater distance. The titlarks

are singing I know, but not within hearing from here; a dove, though, is audible, and a chiffchaff has twice passed. Afar beyond the oaks at the top of the field dark specks ascend from time to time, and after moving in wide circles for awhile descend again to the corn. These must be larks ; but their notes are not powerful enough to reach me, though they would were it not for the song in the hedges, the hum of innumerable insects, and the ceaseless " crake, crake " of landrails. There are at least two landrails in the mowing-grass ; one of them just now seemed coming straight towards the apple tree, and I expected in a minute to see the grass move, when the bird turned aside and entered the tufts and wild parsley by the hedge. Thence the call has come without a moment's pause, " crake, crake," till the thick hedge seems filled with it. Tits have visited the apple tree over my head, a wren has sung in the willow, or rather on a dead branch projecting lower down than the leafy boughs, and a robin across under the elms in the opposite hedge. Elms are a favourite tree of robins—not the upper branches, but those that grow down the trunk, and are the first to have leaves in spring.

The yellowhammer is the most persistent individually, but I think the blackbirds when listened to are the masters of the fields. Before one can finish another begins, like the summer ripples succeeding behind each other, so that the melodious sound merely changes its position. Now here, now in the corner, then across the field, again in the distant copse, where it seems about to sink, when it rises again almost at hand. Like a great human artist, the blackbird makes no effort, being fully conscious that his liquid tone cannot be matched. He utters a few delicious notes, and carelessly quits the green stage of the oak till it pleases him to sing again. Without the blackbird, in whose throat the sweetness of the green fields dwells, the

days would be only partly summer. Without the violet all the bluebells and cowslips could not make a spring, and without the blackbird, even the nightingale would be but half welcome. It is not yet noon, these songs have been ceaseless since dawn ; this evening, after the yellowhammer has sung the sun down, when the moon rises and the faint stars appear, still the cuckoo will call, and the grasshopper lark, the landrail's " crake, crake " will echo from the mound, a warbler or a blackcap will utter his notes, and even at the darkest of the summer night the swallows will hardly sleep in their nests. As the morning sky grows blue, an hour before the sun, up will rise the larks singing and audible now, the cuckoo will recommence, and the swallows will start again on their tireless journey. So that the songs of the summer birds are as ceaseless as the sound of the waterfall which plays day and night.

I cannot leave it ; I must stay under the old tree in the midst of the long grass, the luxury of the leaves, and the song in the very air. I seem as if I could feel all the glowing life the sunshine gives and the south wind calls to being. The endless grass, the endless leaves, the immense strength of the oak expanding, the unalloyed joy of finch and blackbird ; from all of them I receive a little. Each gives me something of the pure joy they gather for themselves. In the blackbird's melody one note is mine ; in the dance of the leaf shadows the formed maze is for me, though the motion is theirs ; the flowers with a thousand faces have collected the kisses of the morning. Feeling with them, I receive some, at least, of their fullness of life. Never could I have enough ; never stay long enough —whether here or whether lying on the shorter sward under the sweeping and graceful birches, or on the thyme-scented hills. Hour after hour, and still not enough. Or walking the footpath was never long

enough, or my strength sufficient to endure till the mind was weary. The exceeding beauty of the earth, in her splendour of life, yields a new thought with every petal. The hours when the mind is absorbed by beauty are the only hours when we really live, so that the longer we can stay among these things so much the more is snatched from inevitable Time. Let the shadow advance upon the dial—I can watch it with equanimity while it is there to be watched. It is only when the shadow is *not* there, when the clouds of winter cover it, that the dial is terrible. The invisible shadow goes on and steals from us. But now, while I can see the shadow of the tree and watch it slowly gliding along the surface of the grass, it is mine. These are the only hours that are not wasted—these hours that absorb the soul and fill it with beauty. This is real life, and all else is illusion, or mere endurance. Does this reverie of flowers and waterfall and song form an ideal, a human ideal, in the mind? It does; much the same ideal that Phidias sculptured of man and woman filled with a godlike sense of the violet fields of Greece, beautiful beyond thought, calm as my turtle-dove before the lurid lightning of the unknown. To be beautiful and to be calm, without mental fear, is the ideal of nature. If I cannot achieve it, at least I can think it.

RICHARD JEFFERIES

MIND UNDER WATER

THE thud, thud of a horse's hoof does not alarm fish. Basking in the sun under the bank, a jack or pike lying close to the surface of the water will remain unmoved, however heavy the sound may be. The vibrations reach the fish in several ways. There is what we

should ourselves call the noise as conveyed by the air, and which in the case of a jack actually at the surface may be supposed to reach him direct. Next there is the vibration passing through the water, which is usually pronounced to be a good medium. Lastly, there is the bodily movement of the substance of the water. When the bank is hard and dry this latter amounts only to a slight shaking, but it frequently happens that the side of a brook or pond is soft, and "gives" under a heavy weight. Sometimes the edge is even pushed into the water, and the brook in a manner squeezed. You can see this when cattle walk by the margin ; the grassy edge is pushed out, and in a minute way they may be said to contract the stream. It is in too small a degree to have the least apparent effect upon the water, but it is different with the sense of hearing, which is so delicate that the bodily movement thus caused may be reasonably believed to be very audible indeed to the jack. The wire fences which are now so much used round shrubberies and across parks give a very good illustration of the conveyance of sound. Strung tight by a spanner, the strands of twisted wire resemble a stringed instrument. If you place your hand on one of the wires and get a friend to strike it with his stick, say, thirty or forty yards away, you will distinctly feel it vibrate. If the ear is held close enough you will hear it, vibration and sound being practically convertible terms. To the basking jack three such wires extend, and when the cart-horse in the meadow puts down his heavy hoof he strikes them all at once. Yet, though fish are so sensitive to sound, the jack is not in the least alarmed, and there can be little doubt that he knows what it is. A whole herd of cattle feeding and walking about does not disturb him, but if the light step—light in comparison—of a man approach, away he goes. Poachers therefore, unable to disguise their footsteps, endeavour

to conceal them, and by moving slowly to avoid vibrating the earth, and through it the water.

Considered in this sense it is interesting to observe to what extent the intelligence even of a fish reaches—and I think upon reflection it will be found that the fish is as clever as any creature could be in its position. I deny altogether that the cold-blooded fish—looked on with contempt so far as its intellectual powers are concerned—is stupid, or slow to learn. On the contrary, fish are remarkably quick, not only under natural conditions, but quick at accommodating themselves to altered circumstances which they could not foresee, and the knowledge how to meet which could not have been inherited. The basking jack is not alarmed at the cart-horse's hoofs, but remains quiet, let them come down with ever so heavy a thud. He has observed that these vibrations never cause him any injury. He hears them at all periods of the day and night, often with long intervals of silence and with every possible variation. Never once has the sound been followed by injury or by anything to disturb his peace. So the rooks have observed that passing trains are harmless, and will perch on the telegraph wires or poles over the steam of the roaring locomotive. Observation has given them confidence. Thunder of wheels and immense weight in motion, the open furnace and glaring light, the faces at the long tier of windows—all these terrors do not ruffle a feather. A little boy with a wooden clapper can set a flock in retreat immediately. Now the rooks could not have acquired this confidence in the course of innumerable generations; it is not hereditary; it is purely what we understand by intelligence. Why are the rooks afraid of the little boy with the clapper? Because they have noticed his hostile intent. Why is the basking jack off the instant he hears the light step of a man?

He has observed that after this step there have often followed attempts to injure him ; a stone has been flung at him, a long pole thrust into the water ; he has been shot at, or felt the pinch of a wire. He remembers this, and does not wait for the attempt to be repeated, but puts himself into safety. If he did not realise that it was a man—and a possible enemy—he would not trouble. The object consequently of the tricks of the poacher is to obliterate himself. If you can contrive to so move, and to so conduct yourself that the fish shall not recognise you as his enemy, you can do much as you please with him, and in varying degrees it is the same with animals. Think a moment by what tokens a fish recognises a man. First, his light, and, compared with other animals, brisk step—a two-step instead of a four-step, remember ; two feet, not four hoofs. There is a difference at once in the rhythm of the noise. Four hoofs can by no possibility produce the same sound, or succession of sounds, as is made even by four feet—that is, by two men. The beats are not the same. 2 Secondly, by his motions, and especially the brisk motions of the arms. 3 Thirdly, by this briskness itself ; for most animals, except man, move with a slow motion—paradox as it may seem—even when they are going along fast. With them it is usually repose in action. Fourthly, and this is rather curious—experience seems to show that fish, and animals and birds certainly,
4 recognise man by his hat or cap, to which they have a species of superstitious dislike.

Hats are generally of a different hue to the rest of the suit, for one thing ; and it was noted, a century ago, that wild creatures have a particular objection to a black hat. A covering to the head at all is so opposite to their own ideas that it arouses suspicion, for we must remember that animals look on our clothes as our skin. To have a black skin over the hair of the

head is somewhat odd. By all these signs a fish knows a man immediately, and as certainly as any creature moving on land would know him. There is no instinctive or hereditary fear of man at all—it is acquired by observation (which a thousand facts demonstrate); so that we are quite justified in believing that a fish really does notice some or all of these attributes of its enemy. What the poacher or wild hunter has to do is to conceal these attributes. To hide the two-step, he walks as slowly as possible, not putting the foot down hard, but feeling the ground first, and gradually pressing it. In this way progress may be made without vibration. The earth is not shaken, and does not communicate the sound to the water. This will bring him to the verge of the place where the fish is basking.

Rain and dry weather change the susceptibility of the surface to vibrate, and may sometimes in part account for the wildness or apparent tameness of birds and animals. Should anyone doubt the existence of such tremors, he has only to lie on the ground with his ear near the surface; but, being unused to the experiment, he will at first only notice the heavier sounds, as of a waggon or a cart-horse. In recent experiments with most delicate instruments devised to show the cosmic vibration of the earth, the movements communicated to it by the tides, or by the "pull" of the sun and moon, it has been found almost impossible as yet to carry out the object, so greatly are these movements obscured by the ceaseless and inexplicable vibrations of the solid earth. There is nothing unreasonable in the supposition that, if an instrument can be constructed to show these, the ears of animals and birds—living organisms, and not iron and steel—should be able to discover the tremors of the surface.

The wild hunter can still further check or altogether prevent observation by moving on hands and knees,

when his weight is widely distributed. In the particular instance of a fish he endeavours to come to the margin of the water at the rear of the fish, whose eyes are so placed that it can see best in front. When he has arrived at the margin, and has to rear himself up, if from hands and knees, or, if already upright, when he commences his work, he tries to conceal his arms, or, rather, to minimise their peculiar appearances as much as practicable by keeping them close to his sides. All this time I am supposing that you are looking at the poacher from the fish. To a fish or any wild animal the arms of a man are suspicious. No other creature that they know possesses these singular appurtenances, which move in almost any direction, and yet have nothing to do with locomotion. You may be sure that this great difference in the anatomical construction of a man is recognised by all wild animals once they are compelled for their own safety to observe him. Arms are so entirely opposite to all the varieties of limb possessed by the varieties of living creatures.

Can you put yourselves in the position of either of these creatures—moving on all-fours, on wings, or by the aid of a membraneous tail and fins, and without arms, and imagine how strange the arms of a man must look? Suppose yourself with your arms tucked to your sides under the fur of an animal; something of the idea may be gathered by putting on a cloak without sleeves or armholes. At once it will be apparent how helpless all creatures are in comparison with man. It is true that apes are an exception; yet their arms are also legs, and they are deficient in the power of the thumb. Man may be defined as an animal with arms. While the creatures of the field or the water have no cause to fear him they do not observe him, but the moment they learn that he is bent on their destruction they watch him narrowly,

and his arms are, above all, the part which alarms them. To them these limbs are man's weapons—his tusks, and tusks which strike and wound afar. From these proceed an invisible force which can destroy where it would seem the intervening distance alone would afford safety. The sharp shot, the keen hook, the lacerating wire, the spear—everything which kills or wounds, comes in some manner or other from the arms, down to the stone or the primitive knobkerrie. Consequently animals, birds, and fishes not only in our own, but in the wildest countries, have learned to watch and to dread man's arms. He raises his arms, and in an instant there shoots forth a bright flash of flame, and before the swift wings can beat the air again the partridge is dashed to the ground.

So long as a gun is carried under the arm—that is, with the arms close to the sides—many birds will let the sportsman approach. Rabbits will do the same. Rabbits have one advantage (and perhaps only one): being numerous and feeding out by daylight, all kinds of experiments can be tried on them, while hares are not so easily managed. Suppose a rabbit feeding, and any one with a gun creeping up beside the hedge, while the gun is kept down and the arms down the rabbit remains still ; the instant the arms are lifted to point the gun, up he sits, or off he goes. You have only to point your arm at a rook, without any gun, to frighten him. Bird-keepers instinctively raise their arms above their heads, when shouting, to startle birds. Every creature that has ever watched man knows that his arms are dangerous. The poacher or wild hunter has to conceal his arms by reducing their movements to a minimum, and by conducting those movements as slowly as possible.

Sometimes, where fish have not been disturbed by poachers, or loafers throwing stones and otherwise annoying them, they will not heed a passer-by, whose

gentle walk or saunter does not affright them with brisk emotion, especially if the saunterer, on espying them, in no degree alters his pace or changes his manner. That wild creatures immediately detect a change of manner, and therefore of mood, any one may demonstrate for himself. They are as quick to see it as the dog, who is always with his master, and knows by the very way he puts a book on the table what temper he is in. When a book goes with a bang on the table the dog creeps under it. Wild creatures, too, catch their manners from man. Walk along a lane with your hands in your pockets, and you will see twice as much of the birds and animals, because they will not set themselves to steadfastly watch you. A quick movement sets wings quickly beating. I have noticed that even horses in stables do not like visitors with jerky, brisk, angular ways of moving. A stranger entering in a quiet, easy manner is not very objectionable, but if he comes in in a bustling, citizen-like style, it is quite probable that one or other horse will show a wicked white corner in his eye. It roughs them up the wrong way. Especially all wild creatures dislike the shuffling, mincing step so common in towns. That alone will disturb everything. Indeed, I have often thought that a good and successful wild hunter—like the backwoodsman, or the sportsman in African bush or Indian jungle—is really made as much by his feet as his eyes or hands. Unconsciously he feels with his feet ; they come to know the exact time to move, whether a long or short stride be desirable, and where to put down, not to rustle or cause a cracking sound, and accommodate themselves to the slope of the ground, touching it and holding it like hands. A great many people seem to have no feet ; they have boots, but no feet. They stamp or clump, or swing their boots along and knock the ground at every step ; this matters not in most callings, but if a man wish to become what I

have called a wild hunter, he must let his feet learn. He must walk with hands in his boots. Now and then a person walks like this naturally, and he will come in and tell you that he has seen a fish basking, a partridge, a hare, or what not, when another never gets near anything. This is where they have not been much disturbed by loafers, who are worse than poachers.

As a rule, poachers are intermittent in their action, and they do not want to disturb the game, as it makes it wild and interferes with their profits. Loafers are not intermittent—they are always about, often in gangs, and destroy others' sports without having any themselves. Near large towns there are places where the fish have to be protected with hurdles thrown across the stream on poles, that the stones and brickbats hurled by every rascal passing may not make their very life a burden. A rural poacher is infinitely preferable. The difference in the ways of fish when they have been much disturbed and when they have been let alone is at once discerned. No sooner do you approach a fish who has been much annoyed and driven than he strikes, and a quick-rotating curl on the surface shows with what vehemence his tail was forced against it. In other places, if a fish perceives you, he gives himself so slight a propulsion that the curl hardly rises, and you can see him gliding slowly into the deeper or overshadowed water. If in terror he would go so quickly as to be almost invisible. In places where the fish have been much disturbed the poacher, or anyone who desires to watch their habits, has to move as slowly as the hands of a clock, and even then they will scarcely bear the very sight of a man, sometimes not at all. The least briskness of movement would send them into the depths out of sight. Cattle, to whom they are accustomed, walk slowly, and so do horses left to themselves in the meads by water. The slowest man walking past has quicker,

perhaps because shorter, movements than those of cattle and horses, so that, even when bushes intervene and conceal his form, his very ways often proclaim him.

Most people will only grant a moderate degree of intelligence to fish, linking coldness of blood to narrowness of intellect, and convinced that there can be but little brain in so small a compass as its head. That the jack can compete with the dog, of course, is out of the question : but I am by no means prepared to admit that fish are so devoid of sense as supposed. Not long since an experiment was tried with a jack, an account of which appeared in the papers. The jack was in a tank, and after a while the tank was partly divided by inserting a plate of glass. He was then hunted round, and notes taken of the number of times he bumped his head against the plate of glass, and how long it took him to learn that there was something to obstruct his path. Further statistics were kept as to the length of his memory when he had learnt the existence of the glass—that is, to see if he would recollect it several days afterwards. The fish was some time learning the position of the glass ; and then, if much alarmed, he would forget its position and dash against it. But he did learn it, and retained his memory some while. It seems to me that this was a very hard and unfair test. The jack had to acquire the idea of something transparent, and yet hard as wood. A moment's thought will show how exactly opposite the qualities of glass are to anything either this particular fish or his ancestors could have met with—no hereditary intelligence to aid him, no experience bearing, however slightly, upon the subject.

Accustomed all his life to transparent water, he had also been accustomed to find it liquid, and easily parted. Put suddenly face to face with the transparent material which repelled him, what was he to think ? Much the same effect would be produced

if you or I, having been accustomed, of course, all our lives, to the fluidity of air, which opens for our passage, were opposed by a solid block of transparent atmosphere. Imagine any one running for a train, and striking his head with all his might against such a block. He would rise, shake himself together, and endeavour to pursue his journey, and be again repelled. More than likely he would try three times before he became convinced that it really was something in the air itself which stopped him. Then he would thrust with his stick and feel, more and more astounded every moment, and scarcely able to believe his own senses. During the day, otherwise engaged, he would argue himself into the view that he had made a mistake, and determine to try again, though more cautiously. But so strong is habit that if a cause for alarm arose, and he started running, he might quite probably go with tremendous force up to the solid block of transparent air, to be hurled back as the jack was.

The reason why fish swim round and round in tanks, and do not beat themselves against the glass walls, is evidently because they can see where the water ends. A distinction is apparent between it and the air outside ; but when the plate of glass was put inside the tank the jack saw water beyond it, or through it. I never see a fish in a tank without remembering this experiment and the long train of reflections it gives rise to. To take a fish from his native brook, and to place him suddenly in the midst of such, to him, inconceivable conditions, is almost like watching the actual creation of mind. His mind has to be created anew to meet it, and that it did ultimately meet the conditions shows that even the fish—the cold-blooded, the narrow-brained—is not confined to the grooves of hereditary knowledge alone, but is capable of wider and novel efforts. I thought the jack came out very

well indeed from the trial, and I have mentioned the matter lest some should think I have attributed too much intelligence to fish.

Other creatures besides fish are puzzled by glass. One day I observed a robin trying to get in at the fan-light of a hall door. Repeatedly he struck himself against it, beat it with his wings, and struggled to get through the pane. Possibly there was a spider inside which tempted him ; but allowing that temptation, it was remarkable that the robin should so strive in vain. Always about houses, he must have had experience of the properties of glass, and yet forgot it so soon. His ancestors for many generations must have had experience of glass, still it did not prevent him making many trials. The slowness of the jack to learn the impenetrable nature of the glass plate and its position is not the least indication of lack of intelligence. In daily life we constantly see people do things they have observed injure them, and yet, in spite of experience, go and do the same again.

The glass experiment proves to me that the jack, like all other creatures, really has a latent power of intelligence beyond that brought into play by the usual circumstances of existence. Consider the conditions under which the jack exists—the jack we have been approaching so carefully. His limits are the brook, the ponds it feeds, and the ditches that enter it. He can only move a short distance up the stream because there is a high hatch, nor can he go far down because of a mill ; if he could, the conditions would be much the same ; but, as a matter of fact, the space he has at his command is not much. The running water, the green flags, the lesser fishes, the water-rats, the horses and cattle on the bank—these are about all the things that he is likely to be interested in. Of these only the water, the lesser fishes, the flags, and the bottom or sides of the brook, are actually in his

touch and complete understanding. As he is unable to live out of water, the horse on the bank, in whose very shadow he sometimes lies, might be a mile away for aught it concerns him. By no possible means can he discover anything about it. The horse may be itself nothing more than a shadow, unless in a shallow place he steps in and splashes. Night and day he knows, the cool night, and the sunbeams in which he basks ; but he has no way of ascertaining the nature of anything outside the water. Centuries spent in such conditions could add but little to his experience.

Does he hear the stream running past him ? Do the particles of water, as they brush his sides and fins, cause a sound, as the wind by us ? While he lurks beneath a weed in the still pool, suddenly a shoal of roach rush by with a sound like a flock of birds whose wings beat the air. The smooth surface of the still water appears to cover an utter silence, but probably to the fish there are ceaseless sounds. Water-fowl feeding in the weedy corners, whose legs depend down into the water and disturb it ; water-rats diving and running along the bottom ; water-beetles moving about ; eels in the mud ; the lower parts of flags and aquatic grasses swinging as the breeze ruffles their tips ; the thud, thud of a horse's hoofs, and now and then the more distant roll of a hay-laden waggon. And thunder—how does thunder sound under the surface ? It seems reasonable to suppose that fish possess a wide gamut of hearing since their other senses are necessarily somewhat curtailed, and that they are peculiarly sensitive to vibratory movements is certain from the destruction a charge of dynamite causes if exploded under water. Even in the deep sea the discharge of a torpedo will kill thousands of herrings. They are, as it were, killed by noise. So that there are grounds for thinking that my quiet jack in the pool, under the bank of the brook, is most keenly

alive by his sense of hearing to things that are proceeding both out and in the water. More especially, no doubt, of things in the water itself. With all this specialised power of hearing he is still circumscribed and limited to the groove of the brook. The birds fly from field to field, from valley to mountain, and across the sea. Their experience extends to whole countries, and their opportunities are constant. How much more fortunate in this respect than the jack! A small display of intelligence by the fish is equivalent to a large display by the bird.

When the jack has been much disturbed no one can do more than obtain a view of him, however skilfully he may conceal himself. The least sign of further proceedings will send the jack away; sometimes the mere appearance of the human form is sufficient. If less suspicious, the rod with the wire attached—or if you wish to make experiments, the rod without the wire—can be placed in the water, and moved how you choose.

RICHARD JEFFERIES

OBSERVATIONS ON THE EEL

THE propagation of the eel was a mystery not only to ordinary people, but also to naturalists, from the time of Aristotle to the end of the nineteenth century, and continued to be a mystery for years after the breeding and development of many other fishes, both marine and fresh-water, had been successfully studied and investigated. At present our knowledge of the development of the eel is almost but not quite complete, and the extraordinary facts of the matter have been brought to light chiefly by the adventurous and persevering efforts of the Danish naturalist, Dr. Johannes

Schmidt, of Copenhagen, who has published a memoir of his researches in the *Philosophical Transactions of the Royal Society of London* and has described them in articles in *Nature* (August 22, 1912, and January 13, 1923).

The gradual elucidation of the history of the eel started from our knowledge of a very curious group of fishes named Leptocephali, which means "Small-heads." They are so named from the fact that the head is very small in proportion to the body, which is like a narrow ribbon $\frac{1}{2}$ to $\frac{3}{4}$ in. in breadth and from 3 to 6 in. in length. The surfaces of the ribbon are the right and left sides of the fish, so that the breadth is vertical in the natural position, and the whole creature is perfectly transparent. The newly hatched young of many fishes are transparent, but they are usually of minute size, while the Leptocephali are much larger. These remarkable creatures had been collected from time to time, some at the surface of the ocean in various parts of the world, some cast on the shore in England or other parts of Europe. Various species of them were distinguished, but for a long time there was nothing to show what relation they bore to other fishes. It was evident that they were not mature, and some naturalists suggested that they were monstrosities, that they were the young of some ordinary fishes which from time to time were accidentally carried into mid-ocean by currents, and there went on growing in size without advancing in structure, that they were in fact over-grown fish-larvae which were unable to complete their normal development because they had been removed from their normal conditions of life. Gradually, however, evidence presented itself that these Leptocephali were connected with the eel family.

Although there is only one fresh-water eel in Europe and another very similar in North America, there are many species of the same family in the sea, some living

at moderate depths and some in the deep abysses of the ocean. On the Atlantic coasts of Europe there is only one marine species, the well-known conger, which reaches 7 or even 8 ft. in length, but there are several species in the Mediterranean, one of which, the Muraena, was a favourite article of food to the ancient Romans. The species of the eel family are similar in certain important features of structure to the herring family, the salmon family, the carp family, and others, but they are distinguished by the entire absence of the hinder pair of fins. In this and other details of structure, such as the number of the vertebrae, the Leptocephali agree with the eels. In particular the *Leptocephalus morrisii*, several specimens of which form had been captured on British and French coasts, was considered to be probably the young of the conger. At last in 1886 a specimen of this form, taken at Roscoff in Normandy in February, was kept alive, and in the period between this month and July actually changed into a young conger, which was dark in colour, cylindrical in shape, and shorter than in the original condition.

After this it appeared extremely probable that the various Leptocephali were the normal young forms or larvae species of the eel family, and that the early condition of the common eel was probably a transparent ribbon-shaped Leptocephalus.

In the years 1891–1894 an Italian professor, G. B. Grassi, and his colleague, Signore Calandruccio, studied carefully the Leptocephali which they obtained at Catania, on the east coast of Sicily. In this neighbourhood, especially near Messina, it had long been known that these peculiar fishes were rather abundant. One of them had been distinguished as *brevirostris* or short-snouted. The Italian naturalists now proved that this particular form changed into the common eel, and, as in the case of the conger, the

perfect young eel was smaller and shorter than the ribbon-like form from which it developed : the latter reaches the length of $3\frac{1}{4}$ in. with a breadth (or vertical height) of $\frac{2}{5}$ in. (0·4 in.) ; and it develops into a slender, thread-like, dark-coloured elver about 2 in. in length.

Elvers, that is to say, young recognisable eels 2 to 3 in. in length, but not less than 2 in., were long known to ascend rivers in enormous numbers in spring. On the banks of the Severn, for example, these little fish can be seen at the right season, March and April, passing up along the banks in countless millions, and the people of the neighbourhood are in the habit of dipping them out of the water with hand nets, and making fish-cakes of them, or otherwise cooking them for food. On the other hand, adult eels are captured in large numbers in autumn passing down the rivers towards the sea, and in Denmark and other places these migrating eels have been shown to be more silvery in colour and to have larger eyes than ordinary specimens. With one or two exceptions, none of them have large roes, so that the exceptions must be regarded as abnormal, and the vast majority of eels go down to the sea to breed, and the young eels come up from the sea to the rivers and fresh waters. There is no evidence that the adult eels ever return from the sea after their migration. It is true also that the male eels are usually found in estuaries or near the mouths of the rivers and do not ascend so far as the females.

It was improbable that the eel larvae should exist only near the coast of Sicily, or only in the Mediterranean, and Dr. Schmidt was first led to give his attention to the subject by the capture of a specimen of *Leptocephalus brevirostris* from the sea near the surface to the west of the Faroe Islands in the far north of the Atlantic. As a result of this it came about that Denmark, where the eel fishery is an important industry,

undertook the task of carrying on the investigation of the eel question, and the direction of the work was entrusted to Dr. Schmidt. This work has been continued from 1904 to 1922 with some interruptions. It consisted chiefly in fishing with special nets in order to ascertain where the larval eels were to be found, at what seasons, and what was their size and condition at each part of the sea. The earlier cruises were made in the steamer *Thor*, which was owned by the Danish Government and specially equipped for marine research. It was found that the Leptocephali of the common eel were found in numbers in the Atlantic from the Faroes to Brittany, outside, *i.e.* to the west of, the 500-fathom line, but not to the east of it. It was shown that in August and September the larvae were undergoing " metamorphosis " or transformation into the perfect eel, and it was evident that the fully developed elvers appearing at the mouths of rivers in spring were derived from the Leptocephali of the previous summer and were at least one year old.

The next task was to discover where the younger larvae occurred. Those above mentioned were the largest in the Leptocephalus stage, just before metamorphosis, and little less or more than 3 in. in length. The Norwegian naturalist, Dr. Hjort, in an Atlantic expedition obtained twenty-one specimens to the south and west of the Azores, and these were only 2 in. in length. It was supposed that these were a year younger than the others and that the actual spawning place was between the Azores and Bermudas. Further collections were made, partly from Danish liners on their voyages across the Atlantic between the English Channel and the West Indies, the special towing-nets for young fishes being supplied to them to be used for an hour or so when possible, and partly from a cruise by a special small schooner called the *Margarethe* fitted out for the purpose. This ship

was wrecked in the West Indies, but the collections were saved. It was found that the smallest larvae, from 9 to 21 mm. in length, were taken in spring and summer about lat. 26° N., long. 55° W., that is, in the Sargasso Sea.

Finally, a four-masted motor schooner, the *Dana*, of 550 tons, was specially fitted out for the purpose of these researches. Expeditions on this ship were made in 1920 and 1921, and large numbers of the larvae were collected at different positions in the western part of the North Atlantic. When the places of capture were plotted out according to the sizes of the larvae, it was proved that all those less than 10 mm. ($\frac{2}{5}$ in.) in length were taken in the middle of the Sargasso Sea, and the larger sizes at increasingly greater distances from this region. This region must be regarded, then, as the spawning place of the European eel. It extends from 20° to 30° N. lat. and from 50° to 65° W. long. In one haul of two hours' duration in this region in June 1920 nearly 800 specimens were obtained, the largest number being 24 mm., or very nearly 1 in. in length. These are considered to be in their first year, probably hatched a few months earlier. The elvers which reach the coast of Europe are calculated to be three years old. The depth of the ocean in the eel-spawning area is from 3000 to 4000 fathoms.

There is one question in which Dr. Schmidt's evidence does not seem quite conclusive, namely, whether the eel spawns in the Mediterranean, or whether all the larvae in that sea come from the Atlantic through the Straits of Gibraltar. There are no eels in the Danube, or in the Black Sea or the Caspian or any of the great rivers flowing into the seas. But there are eels in Egypt, in Greece, Italy, and Spain, and in particular a large eel fishery at Comacchio near Venice. We have seen that the

particular Leptocephalus which belongs to the fresh-water eel was first identified on the coast of Sicily, and Dr. Schmidt has stated that the full-grown larvae were not found by him east of the 500-fathom line, which is inconsistent with the view that they pass through the Straits of Gibraltar. It has been stated, also, that metamorphosed elvers are found at the mouth of the Nile in February, which is as early as, or earlier than, the time for their annual appearance on the west coast of Ireland, although the coast of Egypt is so much farther from the Atlantic breeding-place.

On the other hand, Grassi and Calandruccio do not state that they obtained on the coast of Sicily the youngest and earliest stages of the Leptocephalus of the eel. The depth of the sea to the north of Sicily increases to more than 1000 fathoms and it is possible that this is a sufficient depth for eels to spawn in, but if they do spawn there the very young larvae and the eggs should be captured there. This brings us to the question of the eggs, and Schmidt himself has not yet obtained them from the Atlantic or identified them with certainty. On the other hand, Dr. Raffaele, an extremely able Italian naturalist, studied and described at Naples in 1885–1887 a number of buoyant fish-eggs which, from the characters of the larvae hatched from them, certainly belong to the eel family. The question is : Was one kind of these eggs the egg of the common eel ? One kind had a single oil globule in the yolk, and the youngest of the eel larvae seen by Dr. Schmidt show a single oil globule in the portion of yolk still unabsorbed. But the larva hatched from this egg, although certainly a Leptocephalus, has not been identified with the larva of the common eel. The question, therefore, whether the eel spawns and develops in the Mediterranean cannot yet be answered positively, though the above facts

indicate the possibility, if not the probability, that it does so.

In conclusion, we may mention some remarkable facts concerning both the eel and the conger in the adult state. In the first place, there is a great difference between the sexes in size. The male eel seldom exceeds a length of 18 in., while the females may reach a length of 3 ft. or somewhat more. In the conger the difference is still greater. The present writer made a study of the conger for a considerable time at the Aquarium and Laboratory of the Marine Biological Association at Plymouth. The largest male conger recorded was not quite 2 ft. 6 in. in length, while females 6 ft. in length are common, and specimens up to 8 ft. 3 in. in length are on record. Secondly, although nothing has been seen of mature eels after their descent to the sea, observations of the present writer and one or two others on conger in the aquarium show that both sexes cease to feed when the reproductive organs begin to mature, and they live for three to six months without feeding, and finally die, the females without spawning, the males in a mature condition. When the females die the roes are enormously enlarged though the eggs are not quite mature. But a more extraordinary fact is that the bones have lost all their lime, and become soft as cheese, while the muscles are much reduced. The males before they die get into a much worse condition ; the skin becomes ulcerated, the body emaciated, and the eyes so much diseased that the fish is quite blind. It is evident, therefore, that though the female conger is unable to spawn in the aquarium, this process taking place naturally at depths of more than 1000 fathoms, both sexes spawn only once and die a natural death when the reproductive function has been accomplished.

Dr. Schmidt concludes from his discoveries that the fresh-water eel, which lives the whole of its life after

its metamorphosis in inland fresh waters, but is hatched and developed in the sea and returns to great depths of the ocean to breed, is to be regarded as properly a marine fish. On the other hand, there is good evidence that the earliest bony fishes were evolved in fresh water, and some of the more primitive forms, such as the carp family, are still confined to rivers and lakes ; few of them live exclusively in salt water. Migration from river to sea or sea to river is not uncommon among these more primitive fishes, as, for example, in the salmon family. Here the migration is in the opposite direction from that of the eel ; salmon leave the sea and ascend rivers in order to spawn, and go down to the sea to feed and grow. The Pacific salmon (*Oncorhynchus yschawitscha*) offers a case almost as wonderful as that of the eel. It ascends great rivers of N.W. America and N.E. Asia to distances from 1000 to more than 2000 miles from the coast, and, like the eel, spawns only once and then dies.

J. T. Cunningham

THE ALLIGATORS OF GUIANA

Floating branches and logs are a common sight on the waters of the creeks and rivers of Guiana, and about one in every three of these logs is an alligator. Common in many places and actually abundant in a few, these great saurians are far less conspicuous than their infinitely smaller relatives — the lizards which everywhere scamper up tree-trunks or barge clumsily through the fallen leaves. Several negroes in Georgetown make a living collecting and stuffing young alligators, and one man who had constantly followed this line of work for twenty years had acquired a very thorough knowledge of the ways of

life of these giant reptiles. Among the natives generally they are feared and avoided, and are (mistakenly) accredited with great longevity, of one or two hundred years.

Caimans or crocodiles are not found on the coast, and in fact live only above the first falls or rapids on the rivers whence mythical giant crocodiles are occasionally reported by the Indians.

Alligators occur in most of the rivers, creeks, and even trenches along the coast, and nests are found in Georgetown itself, about a hundred eggs being gathered in the Botanical Gardens each season. The female alligators, when full-grown, measure from $3\frac{1}{2}$ to 5 ft., while the males, in exceptional cases, attain a length of 9 ft.

The actual nesting season begins in May and reaches its height in June. Nests and eggs are still to be found in lessening numbers in July and August, but no eggs have been taken either in April or September. The number laid by each female varies from twenty to forty, each weighing about three ounces. They require at least seventy-five days to hatch. The little 'gators are about 8 in. long, a whole inch of which is gained within a few hours after breaking the shell.

Three weeks before actual laying commences, the female alligator gathers together a pile of water-soaked or decayed vegetation, pulling it up and carrying it in her mouth to some secluded spot on the bank of a trench or creek. Here she piles it and mats it down rather firmly in a rough heap about 2 ft. in height. When alligators have been much bothered or persecuted, they will often select a pegass trench and make their nest on the floating vegetation in the centre, out of the reach of any passing native.

When several weeks have passed, she tears the nest open and lays her eggs in the centre of the hot steaming mass. Unlike the turtles, which lay their eggs in

the sand-banks of the neighbouring rivers, she does not desert the nest, but remains most of the day somewhere in the vicinity. She does not feed there, however, but daily swims to some more distant place. Her food consists of fish, frogs, and snakes, with whatever small animals or birds can be captured, while dead creatures and even carrion are eaten without hesitation. If the feeding ground is at a considerable distance, it is an easy matter to open the nest and examine the eggs undetected, but if the alligator does not have to go far, she will return at the slightest sound.

Alligators differ considerably in their courage. Some will leave the nest after a few weak protests, while others will obstinately remain sprawled over their precious rubbish-heap and have to be killed before their nest can be robbed. The mother alligator remains faithfully at her post until the time of hatching, in which process she gives material assistance. The two and a half months of alternate drenching and baking by rain and sun often cakes the nest mound with a hard-baked crust through which the gatorlings would find it impossible to force their way. So the parent bites into the nest, tossing the outer shell to one side until the pipped eggs or the newly hatched young are exposed. When this is done she rolls out the pipped eggs and, pressing upon them with one of her front feet, she cracks them and liberates the young 'gator. The eggs which are still whole she rolls back among the debris and leaves until the low, nasal, squeaking grunts announce that more are ready to emerge. The young are able to hatch by themselves, but it is usually a very long operation and many die in the shells.

I examined one which had had his little pug-nosed snout thrust through the end of the shell for twenty-four hours and was just about to break a bit away

from the hole when the little reptile shot forth like a jack-in-the-box, freeing himself completely except for his tail. He sprang from my hands into a basin of water, where he dived and swam frantically, the banging of the tail-suspended shell against the tin frightening the newly hatched reptile, and conveying a first impression of the world as a fearsome, undesirable place. He blinked, rose to the surface, shook off the egg-shell, and, turning sideways, snapped at a spot of sunlight. For a day and night, the past twenty-four hours, only the snout had projected. In three seconds more the whole being of the perfect gatorling was functioning, fully launched on what would normally be a long and chequered career.

The mother alligator goes to the nests with the young, and while some swim away and are lost, or forage for themselves, yet many female 'gators are seen at other times of the year accompanied by small ones of two distinct sizes, which the hunters believe are the remnants of the breeds of the two past years, still more or less attendant upon her.

The watchfulness of the parent is of course a trait inherited through long-past centuries, and is in no way consequent upon the very recent, desultory robbing of the nests by man. But it is curious that their worst enemy at present is that most terrible pest introduced by man, from India, the mongoose. The only autochthonous foe is the big tegu, known locally as *salimpenta*. Both of these enemies wait until the parent alligator has gone away and then dig their way down to the eggs. The big yellow-tailed snake has been seen trying to force its way through the crust of the rubbish, but in vain.

The mating season begins in April and is announced by the females calling the males. The proportions of sexes is very unequal, there being twenty or more females to every male. The cry of the female is a

subdued but very strong and penetrating grunt, often repeated. The male's voice is a bellowing or roaring, and when this is heard in the trench, every female within hearing rushes toward him, ten or fifteen sometimes surrounding him at once. After mating, each goes off to her respective nest, where she deposits the entire number of eggs at one laying, afterwards covering them carefully.

The male never goes near the nest, except under very unusual circumstances, and it is in this connection that my alligator hunter indulged his belief in a romantic yarn, which he was convinced was true. I recount it rather as a pleasant bit of negro imagination than as an addition to reptilian psychology. My hunter said that now and then he came across maimed and crippled females which yet had well-built nests full of eggs. One such was an animal which had three feet bitten off, leaving only one hind leg. She could not get up the trench bank without support, and yet her nest was on the top. After trapping her, the hunter concealed himself and called, and was surprised to be answered by a big seven-foot bull 'gator which came out of the water to the nest. In this and several other instances, so my hunter argued, the male must have built the nest, as well as helping the female to get out of the water whenever she returned to it.

When an alligator is trapped or caught in the hand it utters loud chirping squeaks, not unlike the distress cries of some birds. By imitating this, all the alligators within hearing will answer and approach, most of them being females, with now and then an occasional male.

Every season my alligator hunter collects more than 3000 eggs, of which sometimes only about 800 hatch : in every 'gator's nest there are always a number of infertile eggs, ranging from 5 to 20 per cent. In a six weeks' nest, these can readily be detected and thrown

away, but in a nest where the eggs have been deposited only three weeks, the fertile cannot be told from the infertile ones. The fertile eggs remain white, but the bad ones soon turn yellow, at first in spots and later all over. In a healthy egg with a four-weeks embryo, the two end thirds of the egg are pale or flesh colour. The surface of some eggs is almost smooth, but usually the lime incrustations resemble the convolutions of brain coral.

The hunters recognise three kinds of alligators, both young and adults of which they can distinguish on sight. These are known respectively as the Abary, the Goosway, and the Goomasaka. The principal distinguishing characters between the three are the black dorsal markings. Between the front and hind legs there are four, rarely five, transverse black bands. In the Abary most of these bands are interrupted in the middle line of the back ; in the Goosway they form solid, continuous transverse zones of pigment ; while in the Goomasaka the bands on each side of the back line alternate, the lateral halves of one side being opposite the lighter interspace of the opposite side. Every individual 'gator of any one brood always conforms to one or the other of the types, but breeds of intermediate types are occasionally found, and these are considered as the result of inter-breeding of two of the forms.

The Abary and Goosway are the common forms and found over most of the coastal area, while the Goomasaka is very much rarer and confined chiefly to Berbice. These are also reputed much fiercer than the others, more ready to attack any intruder, and to be able to stay for a much longer time under the water. When adult, there are four long teeth in the lower jaw which project through the bone and skin of the upper. The Abary and Goosway, on the contrary, have teeth which are much more even.

Few living alligators are sold. The eggs are gathered, sorted as to degree of development, and kept until hatched in boxes filled with vegetable debris. The alligators are confined in tubs of water and within a day or two are killed and stuffed, standing in absurd postures, erect on their hind legs. For ever after they gaze through shoe-button eyes, and hold their little forearms stiffly out to receive the card-tray for which their future destiny intends them. Tourists, with unbelievable eagerness, purchase these atrocities at a shilling each, doubtless to repose beside wax flowers or to share some dusty northern shelf with a conch shell or a sandalwood box. In spite of this the 'gators of Guiana are holding their own. The toll of infants to be metamorphosed into ornaments is less hurtful to the race than the sacrificing of the skins of the adults for satchels.

William Beebe

MECHANICS

SPINNING TOPS

A DICTIONARY definition of a top is " an inverted conoid which children play with by whirling it on its point."

Before you have finished studying this chapter and performing the experiments detailed therein, you will probably have become fully convinced that a top, more especially when rotating, is much more than this.

First, let us take an ordinary humming top. This not only emits a musical note when spinning (owing to the vibration of little brass reeds consequent on the passage of air through them), but manifests other remarkable properties as well. It possesses a strong and remarkable will of its own. When knocked (not too hard) it does not fall over, but glides away with a peculiar sidelike circling movement. If spun on a slate, it may be tossed into the air, and no longer comes down anyhow, as it would do if it were not spinning, but on its point. This experiment may be repeated several times if the spin be a good one.

Set a spring top spinning on a slate, plate, piece of glass, or any hard surface. Toss it into the air, and catch it as it descends. It comes down point first and goes on spinning. Repeat this experiment but use a disc of smooth wood in order to obtain more friction between the point of the top and the surface. Choose a top with a somewhat sharp point. When tossing it into the air try to make it turn over. If the spin be a good one you will fail to make any impression on the top, which still comes down point first.

Other experiments of a similar character can easily be devised ; and we shall soon become convinced of the following most important fact, that a body when spinning manifests an extraordinary and strong dislike to change the plane in which it is rotating, and when disturbed it does not move off in the direction of the disturbing force.

Take a round stone and roll it along a smooth path. After rolling some distance it comes to rest, partly owing to the friction between it and the ground, partly to its weight, due to the attraction of the earth or gravity (it is really this, of course, that causes the friction), and partly to the resistance of the air.

Take the same stone and roll it along a large, smooth, level sheet of ice, and notice how much farther it travels. Substitute a billiard ball for the stone, and this same distance is again greatly increased. Notice also how the body travels in a straight line unless acted on by some force tending to make it travel otherwise.

By these and similar experiments we are led to the conclusion that if all friction and other forces that act as brakes were removed, a body once started in a certain direction would go on moving in a straight line in that course for ever.

Attach a number of little weights to the ends of the ribs of an umbrella or parasol, and twirl it rapidly round on its axis, the stick. The ribs fly out. The same fact can also be illustrated by means of a piece of wood, say 1 in. square and 3 ft. long, with two flaps about half that length hung by hinges parallel to it. These flaps immediately fly out on the rotation of the long centre-piece.

The toy centrifugal railway is a very striking and pretty illustration of the same principle. Although, whilst travelling from one end of the line to the other, the carriage must twice hang perpendicular, it will

not leave the rail, nor will a coin fall out of it. If the apparatus be large enough, a glass of water even can be placed in the carriage, without its being upset or the contents spilt.

Suspend a bowl or large cup by three cords and twist them by turning the cup round and round. Fill the cup very nearly full with water. Directly the hand is withdrawn, the torsion of the cords causes the cup to rotate, and the water will be found to describe a circle on the floor, flying off at a tangent from the cup.

The same experiment can be shown in even a more effective manner by dipping a mop in a pail of water and twirling the handle round and round between the hands.

We thus see that when a top is spinning, all the particles of which it is composed have a tendency to fly off at a tangent, and would do so if the force of cohesion between the particles did not bind them together and keep them from so doing. In the case of the bowl of water which, when spinning, is nothing more or less than a fluid top, the power of cohesion was so small that the centrifugal force was sufficient to overcome it, and the water was scattered.

Now when a top is spinning quite steadily, popularly known as "sleeping," all the various thin horizontal layers of which we may consider it to be made up are moving on one plane, or, to speak more correctly, in a series of parallel planes. The various parts of the top are all tending to fly off in a series of parallel planes, which is the same thing, so far as we are concerned, as if they were all in one plane. Before the top can fall this plane of rotation has to be altered, and moved through an angle approximately of 90°. This is in direct contradiction to the idea of flying off at a tangent and travelling in a straight line, for by geometry a straight line must lie entirely in one plane.

When a top is rapidly rotating, the various particles of which it is made up are moving in some particular series of parallel planes, and they have a tendency to fly off along this particular set of planes. The axis of rotation cannot be altered without the application of some force. The top is maintained spinning in an upright position by a combination of two forces: (1) the pull of the earth downwards, and (2) the forces due to its rotational movement—acting horizontally in all directions at once.

A spinning or rotating body acquires something more than a dislike to changing its axis of rotation. It maintains also a most remarkable rigidity. Let us again have recourse to experiment.

Take a disc of fairly strong—but not stiff—paper, a foot or eighteen inches in circumference, and fasten it to some little mechanical device by which it can be rapidly rotated. Take, say, an ordinary pencil, thrust its sharp end about half and inch through a flat broad cork or bung, and glue it in position. It thus forms a kind of top with a peg running through it. Glue the sheet or disc of paper to the top or upper side of the bung. Wind a string round the pencil or stick, and, holding the top upright by means of a little cap of brass tubing (closed at one end with a cork or piece of wood) which fits loosely over the pencil, spin it in the ordinary way. The piece of paper is no longer loose, flexible, and flabby, but stiff, rigid, resonant, and unyielding.

Slip a piece of flexible chain over a flat pulley and set the pulley in rapid rotation. Whilst it is so revolving, take a stick and slip the chain quickly off the pulley. It will fall to the ground, but instead of collapsing, it bounces up and goes running along the ground like an ordinary iron or wooden hoop. Its spin has given it two entirely new characteristics, viz. rigidity and elasticity.

Take a wooden box—an ordinary small tea-chest answers admirably—and cut in the side opposite the open end a round hole, not too large. Over the open end glue, or tack tightly if necessary, a sheet of parchment or strong brown paper, or a piece of canvas, making it as taut as possible. In one side of the box bore two holes, just large enough to admit the spouts of two small glass retorts. In one of these place ammonia, and in the other hydrochloric acid. Place under each retort a little spirit-lamp or some other source of heat. The box will quickly become full of dense white fumes of ammonium chloride. If the parchment back of the box be now struck by flicking the finger off the thumb on to it, or with a little flat-head wooden hammer, large and beautiful rings at once issue from the aperture.

Extremely interesting, not to say exciting, experiments may be performed with these vortex rings of air made visible by smoke.

It is extremely interesting to make one smoke ring collide with another. Sometimes they will be shattered, but often they will act like rings of an elastic material, bouncing and recoiling like rubber rings.

Place a lighted candle two yards away from the smoke-box. When hit by one of these air rings (with or without smoke) it is immediately extinguished. The distance can be increased with practice.

Take a glass of clean water and one of the penny ink-fillers for fountain pens (an unused one, of course). Hold the filler so that it nearly touches the surface of the water, and press it so that one single drop of milk (of which a little has previously been drawn up into it in the usual way) falls. As it falls, it produces a beautiful white ring in the water, which at once descends to the bottom. Long ere the bottom is reached, the first formed liquid vortex ring has given rise to several others, and they also, in their turn, to

others ; so that there is soon quite a number of them. The experiment is both very beautiful and very simple.

Every body possesses three principal axes about which it can rotate. Take for instance a cubical block of wood : a hole can be bored through it and an axis (on which it can rotate) be inserted from top to bottom, from side to side—left to right or *vice versa*—and from front to back. Similarly with any other body. In the case of a lemon, an axis can be inserted from end to end, the longer axis, or through the middle at right angles to it, the shorter axis. Now under certain conditions, generally dependent on whether the body be supported above or below its centre of gravity, it develops during its spin a preference for rotating about some particular axis. A struggle takes place between its desire not to change its plane of rotation and its antipathy to spin about any other axis than the preferred one. In the end, if the spin be a good one, the latter always wins.

Take a lemon, and grasping one end in the fingers and thumb of each hand, give it as hard a spin as you can about its shorter axis on a smooth table. The lemon commences spinning, of course on its side, but soon a violent wobbling motion sets in, and finally the lemon rises up on end and continues to spin to the finish in that position.

Try the same experiment with a hard-boiled egg, and a coconut from which the milk has been extracted.

The Earthquake Top

This consists of a hollow metal teetotum (preferably brass) which is capable of being spun either by the fingers or by a string, and is so arranged that one, two, or three small leaden bullets can be dropped into the top whilst it is spinning. If one bullet be dropped in, the top will at once commence to wobble—the larger

the bullet, the more violent the wobble. If, however, a second equally weighted bullet be dropped in, the top will regain its steady motion and be once more in equilibrium ; and if it be suddenly stopped it will be found that the two bullets have arranged themselves exactly opposite one another, or 180° apart.

Similarly, if three bullets be dropped in, they will be found arranged 120° apart, or at the vertices of an equilateral triangle. This interesting top (obtainable from Messrs. Newton & Co., Fleet Street, London) was invented by the Rev. H. V. Gill to illustrate the "sympathetic" theory of earthquakes. It shows that if any disturbance of equilibrium in a spinning body (and the earth is such a spinning body), such as would be caused by an earthquake or sudden shrinkage of the earth's crust, takes place at some particular point of the spinning globe, it must be compensated for by a corresponding alteration at a definite point elsewhere before equilibrium can be re-established.

V. E. Johnson

BOOMERANGS

Among the various weapons and contrivances of savages, none probably has aroused greater interest than the boomerang of the native Australians.

The reason, of course, is on account of its apparent paradoxical behaviour. Simple as it looks, there is a considerable mystery about the implement, and it has indeed almost miraculous properties ascribed to it.

Why ? Because it is said to be able to describe the most wonderful curves and figures in the air ; to hit the object aimed at (a bird, say) and return to the thrower ; to fly round a tree or building and return

on the other side; to come back and circle round the thrower and even fall far behind him.

Now, as to whether the original boomerangs of the Australian natives will do all this or even part of it seems much open to question. Their boomerangs are, with a few exceptions, very rudely shaped curved sticks—no doubt very effective as missiles, but certainly not capable of doing all that the typical boomerang is supposed to do. More than one traveller in the Island Continent has declared the returning boomerang to be a myth. Most certainly it is not so.

There is no difficulty in constructing boomerangs that will perform all the feats just mentioned, with one exception: they cannot be made to hit the quarry and return to the hunter, unless the contact be so slight as to have no effect upon the course of the implement.

The boomerang may take a great variety of forms, but one of the best, if not the best, is constructed of a thin piece of hard tough wood, left flat on one side but rounded on the other, with sharpened edges and rounded ends, and bent in the middle in its own plane at an angle of about 120°. The greatest thickness is about $\frac{1}{3}$ in.; length 2 to $2\frac{1}{2}$ ft.; greatest breadth about $1\frac{1}{2}$ in. Instead of being steamed and bent to the required angle, two pieces neatly mortised together may be used, but the former method is to be preferred. Such is the ideal boomerang. Held by one hand, it can be hurled horizontally (or approximately so) through the air in such a manner as rapidly to rotate. It then "skims" through the air.

Cut out from an ordinary postcard the shape of a boomerang, described above, stick one end beneath your left thumb-nail, flick or snap it with your right forefinger, and send it flying across the room. Choose a large room free from obstacles, or an open space on a calm day. When this little boomerang has reached

the end of its flight what does it do? It at once starts to return.

This experiment is in reality precisely similar to that in which a conjurer throws cards from the theatre stage into the gallery. The feat is at first sight a very remarkable one, but its success depends entirely on so throwing the card that it shall rapidly revolve in its own plane. If it commences to wobble, the resistance of the air will immediately stop it. Once so started, it will keep on flying until the energy put forth in throwing it is used up. It keeps on flying edge-first owing to principles which have already been discussed in a previous chapter, for the boomerang is only another form of a spinning-top.

But why does it return to the sender? Simply because it is easier for it to do that than to do anything else.

Supposing that it has flown out from the sender in the half of a sweeping oval curve, at an angle inclined some 30° to the horizontal, and has arrived at the highest point of its flight. The force which propelled it has been used up—but it is still spinning. Gravity, or the attraction of the earth, which has never ceased to act upon it, now has the upper hand, and it commences to fall. It slides down the same plane by which it went up. To go in any other direction it would have to change its plane, and this its spin prevents it doing; thus it tends to return in the direction of the thrower.

The force of the throw gives the boomerang a strong tendency to move in a certain direction. If it had no spin, its edges cutting the air in an irregular manner would at once set up movements which would soon become so excessive as to result in its turning over and following a course totally different from that imparted to it by the thrower.

The curved or crescent shape greatly assists in

producing that "spin" which is so essential to its success.

Take any ordinary stick—such as a walking-stick—and, holding it by one end, throw it from you; you will find it almost impossible to do this without giving it such a motion that it turns end over end during its flight.

The boomerang-thrower requires, however, a far greater spin than can be got with an ordinary stick. This the sharpened edges help to produce. Any stick or weapon thrown from one end acquires a spin from the swing given in throwing it; but if it be not round but flattened and slightly broad, and grasped by the fingers underneath and the thumb on top, then, from the very manner in which such an article will naturally leave the hand, the spin is still further assisted.

Let us next take a boomerang shaped like a cross. Let the length from top to bottom be 16 in. and across 12 in. If made smaller in size, keep to about these proportions; construct it of thick cardboard or thin tough wood.

Grasp it between the thumb and fingers of the right hand by the long end; then, holding it nearly horizontal, throw it forward across the body from left to right.

It will then revolve from left to right in the same direction as the hands of a clock lying face upwards on a table. It will be found that the boomerang will always curve away towards the left.

Hold the boomerang as before in the right hand, but turn the body through a semicircle, supposing you wish to send it in the same direction as before, and this time throw it across the body from right to left. The boomerang will now be rotating in the opposite direction, and will curve away towards the right.

When thrown correctly it will invariably do this. What is the explanation? The writer's is as follows.

When moving through the air and rotating in the

same direction as the hands of a watch lying face upwards, it is clear that whichever end is moving from six o'clock to twelve o'clock will cut the air more swiftly and forcibly than the end which is moving from twelve to six, for the former has the forward motion of the boomerang considered as a whole increased by the forward movement of the spin—just as the other end has it diminished.

In other words, it is the left-hand end, for the time being, which is the more forcibly acted upon, and consequently that end of the boomerang has the greater tendency to rise.

Bearing in mind, however, the gyroscopical principles, the effect of this is to cause the forward or front part of the gyroscopical boomerang to tilt up ; and this tilting up will be the predominating movement. Now with its front edge higher than the back and its left-hand forward quarter the highest, it will tend to turn upwards and to the left. The boomerang then may make one complete circuit or even more ; the tilting can also become so excessive that the boomerang may turn right over and a reverse curve be the result.

When the spin is in the opposite direction to the hands of a watch, the boomerang will tend to rise as before, but the curve will now be towards the right.

Suppose now that instead of making the boomerang flat on both sides, we leave one side flat and make the other round. If we throw a boomerang of this type in such a manner that the curved side when the implement is moving horizontally is uppermost, it will be found that it possesses greatly improved soaring powers. A boomerang of such section possesses considerable lifting powers even when moving horizontally through the air without any angle of inclination to the line of flight. When the boomerang is spinning hard and moving slowly through the air it tends to keep its plane of rotation constant. When interesting

flights are desired, it should not be thrown too violently ; a sharp jerk at the end of the act of throwing has the effect of imparting a good spin, and a good spin is essential for good flights.

Experiments should only be made out of doors on a calm day. If there be a slight wind, throw the boomerang against it ; in windy weather the flight is erratic and the boomerang is liable to " go anywhere and do anything."

The question may be asked, how was it that such a scientific instrument as the boomerang was invented by the black-fellows of Australia—very low in the scale even of savage races ? Doubtless it was by accident. It must be remembered that the return flight of the boomerang is only half of what the weapon is capable of, and in the early stages of " boomeranging " (to coin a word) probably the less important half. A well-designed boomerang is an instrument which, if skilfully thrown by even a weak man, will travel quite one hundred yards before commencing to return. Such sticks would then first of all be found very suitable for killing all kinds of small game. When the game was not hit it would be found, in course of time, that certain sticks showed a decided tendency to return ; and these would eventually be specially employed for killing wild ducks and fowls on marshes or swamps, where the missiles thrown were not so easily recovered. The bent sticks of the Zuin Indians, which they used for flinging at jack rabbits and breaking their legs, represent the boomerang in its initial stage. On ancient Egyptian monuments men are represented in the act of throwing curved sticks. Possibly they may have been used for killing big birds in the sedges of the Nile. Their general appearance is not, however, such as would lead one to suppose that they would return.

V. E. Johnson

EXPLORATION

A SCIENTIST'S HUT IN THE ANTARCTIC

Tuesday, January 10.—We have been six days in McMurdo Sound and to-night I can say we are landed. Were it impossible to land another pound we could go on without hitch. Nothing like it has been done before; nothing so expeditious and complete. This morning the main loads were fodder. Sledge after sledge brought the bales, and early in the afternoon the last was brought on shore. Some addition to our patent fuel was made in the morning, and later in the afternoon it came in a steady stream. We have more than 12 tons and could make this do if necessity arose.

In addition to this, oddments have been arriving all day—instruments, clothing, and personal effects. Our camp is becoming so perfect in its appointments that I am almost suspicious of some drawback hidden by the summer weather.

The hut is progressing apace, and all agree that it should be the most perfectly comfortable habitation. "It amply repays the time and attention given to the planning." The sides have double boarding inside and outside the frames, with a layer of our excellent quilted seaweed insulation between each pair of boardings. The roof has a single matchboarding inside, but on the outside is a matchboarding, then a layer of 2-ply "ruberoid," then a layer of quilted seaweed, then a second matchboarding, and finally a cover of 3-ply "ruberoid." The first floor is laid,

but over this there will be a quilting, a felt layer, a second boarding, and finally linoleum ; as the plenteous volcanic sand can be piled well up on every side it is impossible to imagine that draughts can penetrate into the hut from beneath, and it is equally impossible to imagine great loss of heat by contact or radiation in that direction. To add to the wall insulation the south and east sides of the hut are piled high with compressed-forage bales, whilst the north side is being prepared as a winter stable for the ponies. The stable will stand between the wall of the hut and a wall built of forage bales, six bales high and two bales thick. This will be roofed with rafters and tarpaulin, as we cannot find enough boarding. We shall have to take care that too much snow does not collect on the roof, otherwise the place should do excellently well.

Wednesday, January 11.—The day was altogether too bad for outside work, so we turned our attention to the hut interior, with the result that to-night all the matchboarding is completed. The floor linoleum is the only thing that remains to be put down ; outside, the roof & ends have to be finished. Then there are several days of odd jobs for the carpenter, and all will be finished. It is a first-rate building in an extraordinarily sheltered spot ; whilst the wind was raging at the ship this morning we enjoyed comparative peace. Campbell says there was an extraordinary change as he approached the beach.

I sent two or three people to dig into the hard snow drift behind the camp; they got into solid ice immediately, became interested in the job, and have begun the making of a cave which is to be our larder. Already they have tunnelled 6 or 8 feet in and have begun side channels. In a few days they will have made quite a spacious apartment—an ideal place to keep our meat store. We had been speculating as to

the origin of this solid drift and attached great antiquity to it, but the diggers came to a patch of earth with skua feathers, which rather knocks our theories on the head.

Thursday, January 12.—Bright sun again all day, but in the afternoon a chill wind from the S.S.W. Again we are reminded of the shelter afforded by our position; to-night the anemometers on Observation Hill show a 20-mile wind—down in our valley we only have mild puffs.

Early in the afternoon a message came from the ship to say that all stores had been landed. Nothing remains to be brought but mutton, books and pictures, and the pianola. So at last we really are a self-contained party ready for all emergencies. We are LANDED eight days after our arrival—a very good record.

The hut could be inhabited at this moment, but probably we shall not begin to live in it for a week. Meanwhile the carpenter will go on steadily fitting up the dark-room and various other compartments as well as Simpson's Corner.

The grotto party are making headway into the ice for our larder, but it is slow and very arduous work. However, once made it will be admirable in every way.

The hut and grotto parties will continue, and the arrangements for the depot journey will be commenced. I discussed these with Bowers this afternoon—he is a perfect treasure, enters into one's ideas at once, and evidently thoroughly understands the principles of the game.

I have arranged to go to Hut Point with Meares and some dogs to-morrow to test the ice and see how the land lies. As things are at present we ought to have little difficulty in getting the depot party away any time before the end of the month, but the ponies

will have to cross the Cape without loads. There is a way down on the south side straight across, and another way round, keeping the land on the north side and getting on ice at the Cape itself. Probably the ship will take the greater part of the loads.

Saturday, January 14.—The completion of our station is approaching with steady progress.

It was good to return to the camp and see the progress which had been made even during such a short absence. The grotto has been much enlarged and is, in fact, now big enough to hold all our mutton and a considerable quantity of seal and penguin.

Close by Simpson and Wright have made surprising progress in excavating for the differential magnetic hut. They have already gone in 7 feet and, turning a corner, commenced the chamber, which is to be 13 feet × 5 feet. The hard ice of this slope is a godsend, and both grottos will be ideal for their purposes.

The cooking range and stove have been placed in the hut and now chimneys are being constructed; the porch is almost finished as well as the interior; the various carpenters are busy with odd jobs and it will take them some time to fix up the many small fittings that different people require.

I have been making arrangements for the depot journey, telling off people for ponies and dogs, &c.

Monday, January 16.—We slept badly till the morning and, therefore, late. After breakfast we went up the hills; there was a keen S.E. breeze, but the sun shone and my spirits revived. There was very much less snow everywhere than I have ever seen. We got to camp about tea-time. I found our larder in the grotto completed and stored with mutton and penguins—the temperature inside has never been above 27°, so that it ought to be a fine place for our winter store. Simpson has almost completed the differential magnetic cave next door. The hut stove

was burning well and the interior of the building already warm and homelike—a day or two and we shall be occupying it.

Tuesday, January 17.—We took up our abode in the hut to-day and are simply overwhelmed with its comfort. After breakfast this morning I found Bowers making cubicles as I had arranged, but I soon saw these would not fit in, so instructed him to build a bulkhead of cases which shuts off the officers' space from the men's, I am quite sure to the satisfaction of both. The space between my bulkhead and the men's I allotted to five: Bowers, Oates, Atkinson, Meares, and Cherry-Garrard. These five are all special friends and have already made their dormitory very habitable. Simpson and Wright are near the instruments in their corner. Next come Day and Nelson in a space which includes the latter's "Lab." near the big window; next to this is a space for three—Debenham, Taylor, and Gran; they also have already made their space part dormitory and part workshop.

It is fine to see the way every one sets to work to put things straight; in a day or two the hut will become the most comfortable of houses, and in a week or so the whole station, instruments, routine, men and animals, etc., will be in working order.

It is really wonderful to realise the amount of work which has been got through of late.

It will be *a fortnight to-morrow* since we arrived in McMurdo Sound, and here we are absolutely settled down and ready to start on our depot journey directly the ponies have had a proper chance to recover from the effects of the voyage. I had no idea we should be so expeditious.

Wednesday, January 18.—The position of the ship makes the casual transport that still proceeds very easy, but the ice is rather thin at the edge. In the hut all is marching towards the utmost comfort.

Bowers has completed a storeroom on the south side, an excellent place to keep our travelling provisions. Every day he conceives or carries out some plan to benefit the camp. Simpson and Wright are worthy of all admiration: they have been unceasingly active in getting things to the fore and I think will be ready for routine work much earlier than was anticipated. But, indeed, it is hard to specialise praise where everyone is working so indefatigably for the cause.

Each man in his way is a treasure.

Clissold the cook has started splendidly, has served seal, penguin, and skua now, and I can honestly say that I have never met these articles of food in such a pleasing guise: "this point is of the greatest practical importance, as it means the certainty of good health for any number of years." Hooper was landed to-day, much to his joy. He got to work at once, and will be a splendid help, freeing the scientific people of all dirty work. Anton and Demetri are both most anxious to help on all occasions; they are excellent boys.

Thursday, January 19.—The hut is becoming the most comfortable dwelling-place imaginable. We have made unto ourselves a truly seductive home, within the walls of which peace, quiet, and comfort reign supreme.

Such a noble dwelling transcends the word "hut," and we pause to give it a more fitting title only from lack of the appropriate suggestion. What shall we call it?

"The word 'hut' is misleading. Our residence is really a house of considerable size, in every respect the finest that has ever been erected in the Polar regions; 50 ft. long by 25 wide and 9 ft. to the eaves."

"If you can picture our house nestling below this small hill on a long stretch of black sand, with many tons of provision cases ranged in neat blocks in front

of it and the sea lapping the ice-foot below, you will have some idea of our immediate vicinity. As for our wider surroundings it would be difficult to describe their beauty in sufficiently glowing terms. Cape Evans is one of the many spurs of Erebus and the one that stands closest under the mountain, so that always towering above us we have the grand snowy peak with its smoking summit. North and south of us are deep bays, beyond which great glaciers come rippling over the lower slopes to thrust high blue-walled snouts into the sea. The sea is blue before us, dotted with shining bergs or ice floes, whilst far over the Sound, yet so bold and magnificent as to appear near, stand the beautiful Western Mountains with their numerous lofty peaks, their deep glacial valley and clear cut scarps, a vision of mountain scenery that can have few rivals."

" Ponting is the most delighted of men ; he declares this is the most beautiful spot he has ever seen, and spends all day and most of the night in what he calls ' gathering it in ' with camera and cinematograph."

The wind has been boisterous all day, to advantage after the last snow fall, as it has been drifting the loose snow along and hardening the surfaces. The horses don't like it, naturally, but it wouldn't do to pamper them so soon before our journey. I think the hardening process must be good for animals though not for men ; Nature replies to it in the former by growing a thick coat with wonderful promptitude. It seems to me that the shaggy coats of our ponies are already improving. The dogs seem to feel the cold little so far, but they are not so exposed.

A milder situation might be found for the ponies if only we could picket them off the snow.

Bowers has completed his southern storeroom and brought the wing across the porch on the windward side, connecting the roofing with that of the porch.

The improvement is enormous and will make the greatest difference to those who dwell near the door.

The carpenter has been setting up standards and roof beams for the stables, which will be completed in a few days.

This morning I overhauled all the fur sleeping-bags and found them in splendid order—on the whole the skins are excellent. Since that I have been trying to work out sledge details, but my head doesn't seem half as clear on the subject as it ought to be.

I have fixed the 25th as the date for our departure. P.O. Evans is to get all the sledges and gear ready whilst Bowers superintends the filling of provision bags.

Ponting has fitted up his dark-room—doing the carpentering work with extraordinary speed and to every one's admiration. To-night he made a window in the dark-room in an hour or so.

Meares has become enamoured of the gramophone. We find we have a splendid selection of records. The pianola is being brought in sections, but I'm not at all sure it will be worth the trouble. Oates goes steadily on with the ponies—he is perfectly excellent and untiring in his devotion to the animals.

Day and Nelson, having given much thought to the proper fitting up of their corner, have now begun work. There seems to be little doubt that these ingenious people will make the most of their space.

I have done quite a lot of thinking over the autumn journeys and much remains to be done, mainly on account of the prospect of being cut off from our winter quarters ; for this reason we must have a great deal of food for animals and men.

Friday, January 20.—Our house has assumed great proportions. Bowers' annexe is finished, roof and all thoroughly snow-tight ; an excellent place for spare clothing, furs, and ready use stores, and its extension

affording complete protection to the entrance porch of the hut. The stables are nearly finished—a thoroughly stout, well-roofed lean-to on the north side. Nelson has a small extension on the east side and Simpson a prearranged projection on the S.E. corner, so that on all sides the main building has thrown out limbs. Simpson has almost completed his ice cavern, light-tight lining, niches, floor and all. Wright and Forde have almost completed the absolute hut, a patchwork building for which the framework only was brought—but it will be very well adapted for our needs.

Gran has been putting " record " on the ski runners. Record is a mixture of vegetable tar, paraffin, soft soap, and linseed oil, with some patent addition which prevents freezing—according to Gran.

P.O. Evans and Crean have been preparing sledges; Evans shows himself wonderfully capable, and I haven't a doubt as to the working of the sledges he has fitted up.

The pianola has been erected by Rennick. He is a good fellow. The pianola has been his special care, and it shows well that he should give so much pains in putting it right for us.

Impressions on Returning to the Hut

(Impressions on returning to the Hut, April 13, 1911, after laying depots for next year's expedition to the Pole)

In choosing the site of the hut on our Home Beach I had thought of the possibility of northerly winds bringing a swell, but had argued, first, that no heavy northerly swell had ever been recorded in the Sound; secondly, that a strong northerly wind was bound to bring pack which would damp the swell; thirdly, that the locality was excellently protected by the Barne Glacier; and finally, that the beach itself showed no signs of having been swept by the sea,

the rock fragments composing it being completely angular.

When the hut was erected and I found that its foundation was only 11 feet above the level of the sea ice, I had a slight misgiving, but reassured myself again by reconsidering the circumstances that afforded shelter to the beach.

The fact that such a question had been considered makes it easier to understand the attitude of mind that readmitted doubt in the face of phenomenal conditions.

The event has justified my original arguments, but I must confess a sense of having assumed security without sufficient proof in a case where an error of judgment might have had dire consequences.

It was not until I found all safe at the Home Station that I realised how anxious I had been concerning it. In a normal season no thought of its having been in danger would have occurred to me, but since the loss of the ponies and the breaking of the Glacier Tongue I could not rid myself of the fear that misfortune was in the air and that some abnormal swell had swept the beach; gloomy thoughts of the havoc that might have been wrought by such an event would arise in spite of the sound reasons which had originally led me to choose the site of the hut as a safe one.

The late freezing of the sea, the terrible continuance of wind and the abnormalities to which I have referred had gradually strengthened the profound distrust with which I had been forced to regard our mysterious Antarctic climate until my imagination conjured up many forms of disaster as possibly falling on those from whom I had parted for so long.

We marched towards Cape Evans under the usually miserable conditions which attend the breaking of camp in a cold wind after a heavy blizzard. The outlook was dreary in the grey light of early morning,

our clothes were frozen stiff and our fingers, wet and cold in the tent, had been frost-bitten in packing the sledges.

A few comforting signs of life appeared as we approached the Cape: some old footprints in the snow, a long silk thread from the meteorologist's balloon; but we saw nothing more as we neared the rocks of the promontory and the many grounded bergs which were scattered off it.

To my surprise the fast ice extended past the Cape and we were able to round it into the North Bay. Here we saw the weather screen on Wind Vane Hill, and a moment later turned a small headland and brought the hut in full view. It was intact—stables, outhouses, and all; evidently the sea had left it undisturbed. I breathed a huge sigh of relief. We watched two figures at work near the stables and wondered when they would see us. In a moment or two they did so, and fled inside the hut to carry the news of our arrival. Three minutes later all nine occupants were streaming over the floe towards us with shouts of welcome. There were eager inquiries as to mutual welfare and it took but a minute to learn the most important events of the quiet station life which had been led since our departure. These under the circumstances might well be considered the deaths of one pony and one dog. The pony was that which had been nicknamed Hackenschmidt from his vicious habit of using both fore and hind legs in attacking those who came near him. He had been obviously of different breed from the other ponies, being of lighter and handsomer shape, suggestive of a strain of Arab blood. From no cause which could be discovered either by the symptoms of his illness or the post-mortem held by Nelson could a reason be found for his death. In spite of the best feeding and every care he had gradually sickened until he was too weak

to stand, and in this condition there had been no option but to put him out of misery. Anton considers the death of Hackenschmidt to have been an act of " cussedness "—the result of a determination to do no work for the Expedition !! Although the loss is serious, I remember doubts which I had as to whether this animal could be anything but a source of trouble to us. He had been most difficult to handle all through, showing a vicious, intractable temper. I had foreseen great difficulties with him, especially during the early part of any journey on which he was taken, and this consideration softened the news of his death. The dog had been left behind in a very sick condition, and this loss was not a great surprise.

These items were the worst of the small budget of news that awaited me ; for the rest, the hut arrangements had worked out in the most satisfactory manner possible and the scientific routine of observations was in full swing.

After our primitive life at Cape Armitage it was wonderful to enter the precincts of our warm, dry Cape Evans home. The interior space seemed palatial, the light resplendent, and the comfort luxurious. It was very good to eat in civilised fashion, to enjoy the first bath for three months, and have contact with clean, dry clothing. Such fleeting hours of comfort (for custom soon banished their delight) are the treasured remembrance of every Polar traveller. They throw into sharpest contrast the hardships of the past and the comforts of the present, and for the time he revels in the unaccustomed physical contentment that results.

I was not many hours or even minutes in the hut before I was dragged round to observe in detail the transformation which had taken place during my absence, and in which a very proper pride was taken by those who had wrought it.

Simpson's Corner was the first visited. Here the eye travelled over numerous shelves laden with a profusion of self-recording instruments, electric batteries and switchboards, whilst the ear caught the ticking of many clocks, the gentle whirr of a motor, and occasionally the trembling note of an electric bell. But such sights and sounds conveyed only an impression of the delicate methodical means by which the daily and hourly variations of our weather conditions were being recorded—a mere glimpse of the intricate arrangements of a first-class meteorological station—the one and only station of that order which has been established in Polar regions. It took me days and even months to realise fully the aims of our meteorologist and the scientific accuracy with which he was achieving them. The first impression, which I am here describing, was more confused ; I appreciated only that by going to " Simpson's Corner " one could ascertain at a glance how hard the wind was blowing and had been blowing, how the barometer was varying, to what degree of cold the thermometer had descended ; if one were still more inquisitive he could further inform himself as to the electrical tension of the atmosphere and other matters of like import. That such knowledge could be gleaned without a visit to the open air was an obvious advantage to those who were clothing themselves to face it, whilst the ability to study the variation of a storm without exposure savoured of no light victory of mind over matter.

The dark-room stands next to the parasitologist's side of the bench which flanks Sunny Jim's Corner —an involved sentence. To be more exact, the physicists adjust their instruments and write up books at a bench which projects at right angles to the end wall of the hut ; the opposite side of this bench is allotted to Atkinson, who is to write with his back to the dark-room. Atkinson being still absent his corner

was unfurnished, and my attention was next claimed by the occupant of the dark-room beyond Atkinson's limit. The art of photography has never been so well housed within the Polar regions and rarely without them. Such a palatial chamber for the development of negatives and prints can only be justified by the quality of the work produced in it, and is only justified in our case by the possession of such an artist as Ponting. He was eager to show me the results of his summer work, and meanwhile my eye took in the neat shelves with their array of cameras, etc., the porcelain sink and automatic water tap, the two acetylene gas burners with their shading screens, and the general obviousness of all conveniences of the photographic art. Here, indeed, was encouragement for the best results, and to the photographer be all praise, for it is mainly his hand which has executed the designs which his brain conceived. In this may be clearly seen the advantage of a traveller's experience. Ponting has had to provide for himself under primitive conditions in a new land; the result is a "handy man" with every form of tool and in any circumstances. Thus, when building operations were to the fore and mechanical labour scarce, Ponting returned to the shell of his apartment with only the raw material for completing it. In the shortest possible space of time shelves and tanks were erected, doors hung and windows framed, and all in a workmanlike manner commanding the admiration of all beholders. It was well that speed could be commanded for such work, since the fleeting hours of the summer season had been altogether too few to be spared from the immediate service of photography. Ponting's nervous temperament allowed no waste of time—for him fine weather meant no sleep; he decided that lost opportunities should be as rare as circumstances would permit.

This attitude was now manifested in the many yards of cinematograph film remaining on hand and yet greater number recorded as having been sent back in the ship, in the boxes of negatives lying on the shelves and a well-filled album of prints.

Of the many admirable points in this work, perhaps the most notable are Ponting's eye for a picture and the mastery he has acquired of ice subjects ; the composition of most of his pictures is extraordinarily good, he seems to know by instinct the exact value of foreground and middle distance and of the introduction of " life," whilst with more technical skill in the manipulation of screens and exposures he emphasises the subtle shadows of the snow and reproduces its wondrously transparent texture. It is good to hear his enthusiasm for results of the past and plans for the future.

Long before I could gaze my fill at the contents of the dark-room I was led to the biologist's cubicle ; Nelson and Day had from the first decided to camp together, each having a habit of methodical neatness ; both were greatly relieved when the arrangement was approved, and they were freed from the chance of an untidy companion. No attempt had been made to furnish this cubicle before our departure on the autumn journey, but now on my return I found it an example of the best utilisation of space. The prevailing note was neatness ; the biologist's microscope stood on a neat bench surrounded by enamel dishes, vessels, and books neatly arranged ; behind him, when seated, rose two neat bunks with neat, closely curtained drawers for clothing and neat reflecting sconces for candles ; overhead was a neat arrangement for drying socks, with several nets, neatly bestowed. The carpentering to produce this effect had been of quite a high order, and was in very marked contrast with that exhibited for the hasty erections in other

cubicles. The pillars and boarding of the bunks had carefully finished edges and were stained to mahogany brown. Nelson's bench is situated very conveniently under the largest of the hut windows, and had also an acetylene lamp, so that both in summer and winter he has all conveniences for his indoor work.

Day appeared to have been unceasingly busy during my absence. Every one paid tribute to his mechanical skill and expressed gratitude for the help he had given in adjusting instruments and generally helping forward the scientific work. He was entirely responsible for the heating, lighting, and ventilating arrangements, and as all these appear satisfactory he deserved much praise. Particulars concerning these arrangements I shall give later ; as a first impression it is sufficient to note that the warmth and lighting of the hut seemed as good as could be desired, whilst for our comfort the air seemed fresh and pure. Day had also to report some progress with the motor sledges, but this matter also I leave for future consideration.

My attention was very naturally turned from the heating arrangements to the cooking stove and its custodian, Clissold. I had already heard much of the surpassingly satisfactory meals which his art had produced, and had indeed already a first experience of them. Now I was introduced to the cook's corner with its range and ovens, its pots and pans, its side tables and well-covered shelves. Much was to be gathered therefrom, although a good meal by no means depends only on kitchen conveniences. It was gratifying to learn that the stove had proved itself economical and the patent fuel blocks a most convenient and efficient substitute for coal. Save for the thickness of the furnace cheeks and the size of the oven, Clissold declared himself wholly satisfied. He feared that the oven would prove too small to keep up a constant supply of bread for all hands ; nevertheless he

introduced me to this oven with an air of pride which I soon found to be fully justified. For connected therewith was a contrivance for which he was entirely responsible, and which in its ingenuity rivalled any of which the hut could boast. The interior of the oven was so arranged that the " rising " of the bread completed an electric circuit, thereby ringing a bell and switching on a red lamp. Clissold had realised that the continuous ringing of the bell would not be soothing to the nerves of our party, nor the continuous burning of the lamp calculated to prolong its life, and he had therefore added the clockwork mechanism which automatically broke the circuit after a short interval of time ; further, this clockwork mechanism could be made to secure the repetition of the same warning signals at intervals of time varied according to the desire of the operator ;—thus because, when in bed, he would desire a signal at short periods, but if absent from the hut he would wish to know at a glance what had happened when he returned. Judged by any standard it was a remarkably pretty little device, but when I learnt that it had been made from odds and ends, such as a cog-wheel or spring here and a cell or magnet there, begged from other departments, I began to realise that we had a very exceptional cook. Later, when I found that Clissold was called in to consult on the ailments of Simpson's motor and that he was capable of constructing a dog sledge out of packing cases, I was less surprised, because I knew by this time that he had had considerable training in mechanical work before he turned his attention to pots and pans.

My first impressions include matters to which I was naturally eager to give an early half-hour, namely, the housing of our animals. I found herein that praise was as justly due to our Russian boys as to my fellow Englishmen. Anton, with Lashly's help, had

completed the furnishing of the stables. Neat stalls occupied the whole length of the "lean-to," the sides so boarded that sprawling legs could not be entangled beneath and the front well covered with tin sheet to defeat the "cribbers." I could but sigh again to think of the stalls that must now remain empty, whilst appreciating that there was ample room for the safe harbouring of the ten beasts that remained, be the winter never so cold or the winds so wild.

Later we have been able to give double space to all but two or three of our animals, in which they can lie down if they are so inclined.

The ponies looked fairly fit considering the low diet on which they had been kept; their coats were surprisingly long and woolly in contrast with those of the animals I had left at Hut Point. At this time they were being exercised by Lashly, Anton, Demetri, Hooper, and Clissold, and as a rule were ridden, the sea having only recently frozen. The exercise ground had lain on the boulder-strewn sand of the home beach and extending towards the Skua lake; and across these stretches I soon saw barebacked figures dashing at speed, and not a few amusing incidents in which horse and rider parted with abrupt lack of ceremony. I didn't think this quite the most desirable form of exercise for the beasts, but decided to leave matters as they were till our pony manager returned.

Demetri had only five of six dogs left in charge, but these looked fairly fit, all things considered, and it was evident the boy was bent on taking every care of them, for he had not only provided shelters, but had built a small "lean-to" which would serve as a hospital for any animal whose stomach or coat needed nursing.

Such were in broad outline the impressions I received on my first return to our home station; they

were almost wholly pleasant and in happy contrast with the fears that had assailed me on the homeward route. As the days went by I was able to fill in the detail in equally pleasant fashion, to watch the development of fresh arrangements and the improvement of old ones. Finally, in this way I was brought to realise what an extensive and intricate but eminently satisfactory organisation I had made myself responsible for.

CAPTAIN R. F. SCOTT

RESEARCH IN A TROPICAL JUNGLE

To settle down in a strange country and to study successfully the wild creatures which inhabit it demands a few of the elements of real warfare, combined, however, with a large percentage of luck, the chances of a gamble. But this last comprises, after all, much of the formula of all organic research, the factor which imbues it with the peculiar fascination absent from more mathematically precise phases of work.

With steel traps, guns and cartridges, nets and seines, there is no difficulty in accumulating a host of dead and captive specimens, but this any professional collector could do, and do better, than we. We had to contend with the problems concerned in discovering, watching, and finally, if necessary, securing, dead or alive, certain definite species or groups of organisms. And this was a very different matter, and of all places difficult here in the tropics, where a single glimpse of a certain species might be all that was vouchsafed for many months.

In studying any one group we found it necessary to work out correlated association with other phases of life, or to watch meteorological conditions. Certain

insects emerged only immediately after heavy afternoon rains. If we wished to find birds such as fork-tailed flycatchers during the moulting season, we carried the sequence of events one link farther. After heavy rain we searched for a flight of termites in the open, and there we were certain to find the birds. To depend on indirect signs became almost second nature.

Were we desirous of learning the alarm note of the white-fronted ant-catcher? That spry little bird of the jungle undergrowth with its erect halo of snow-white plumes could always be counted on in the van of an army of driver ants. But to locate the ants themselves in the jungle was easy only after we had learned to listen for the mingled chirps of the smaller, more voluble species of ant-birds which had adopted this easy method of securing a supply of insect food.

We came with a supply of small mouse-traps and larger steel ones, and, after we arrived, made box and figure-of-four traps. But we had overlooked the fact that this was a world of hungry ants, and for a time our collector had poor success. For the most easily trapped mammal would hesitate at a delectable bait when it was covered three deep with stinging ants. Then elaborate ant-proof contrivances were evolved, guarded by moats and slightly raised platforms and zones of sticky sap. But this brought the bait to the notice of stray vultures, and after that we were kept busy releasing the yellow-headed scavengers which came down from the heart of the sky to the new-found manna. A study of ant diet revealed certain items for which they did not care, and these, chiefly vegetable, were successful, being inedible alike to ant and vulture.

Mice and rats of the jungle were exceedingly difficult to capture. Now and then while out on other work we caught glimpses of them, but they utterly

refused to enter the most open trap set with the most enticing bait. And I was disappointed in the showing of frogs and toads which I wanted to ship north alive. We could hear them at night, and their tadpoles were abundant in the creeks and pools, but the long evening's work with flash and net often yielded a bare half-dozen, all perhaps of the same species.

As was more than once the case, my ultimate success in these directions was due wholly to chance, and not at all to any careful planning or invention. I had a deep hole dug at the southern edge of Kalacoon compound, intending to fill it with refuse. The day after the coolie workmen completed their part I looked in and, to my surprise, saw two frogs of a species new to me, sitting and blinking at one another, while on the opposite side of the bottom of the pit a wild rat of a rich rufous colour was vainly trying to conceal himself beneath a fallen leaf some three sizes too small. I had been uninventive enough never to think of this plan but at least I did not need a second hint, and immediately I set my Indian boys to work, at what was doubtless sheer insanity to them, digging a line of pits along the convict trail which led southward, and several more in the jungle itself. After this, one of us always made a morning's round of pits, as the Canadian hunter visits his beaver and marten traps. Sometimes we made excellent hauls which were all the more enjoyable because our booty was not mangled and half-dead, but alive and well.

Huge beetles and thousand-legs blundered into the pits, but we never found a snake or lizard in them. These seemed to feel their way too carefully to be entrapped in any such blatant fashion. Some of the pits were in clay, others in white sand ; some caught every heavy rain and had to be provided with life rafts of small pieces of bark so the inmates could keep themselves afloat. The sand-pits were eaten away

from above by the rains and required redigging every little while. Altogether it was an easy and exciting method of obtaining certain of the lesser ramblers of the night, of whom we otherwise should have learned nothing.

To the nests of solitary wasps, which were one of our chiefest desires, there was little clue except by direct search. Many were found accidentally, and more by seeing the wasp arrive with a load of mortar or a spider. It was tantalising to watch an interesting species busily at work on the damp clay of one of our pits, making trip after trip to some fascinating cell, and yet to be unable to trace her more than a few yards as she sped swiftly through the maze of vines and leaves. The longest tramp in a distant part of the jungle might result in nothing, while on one's return, if the key had been removed from the microscope case on the table, a new species of wasp would not impossibly be found enthusiastically building in the lock !

Owing to the dullness of our senses and the unwieldiness of our bodies, to study successfully the small folk of the jungle we had to resort to many artificial means, usually some method of causing them to assemble at a desired spot. We have seen how gravitation was used in the case of the pits. We also use scent, such as exposing the female of some insect in an open cage and waiting for males of the same species to come upwind. Or we placed dishes of partly dissolved sugar, made still more irresistible by the addition of a little gin, along the trails and seldom failed to find great blue morphos and other butterflies and bees drinking to repletion. A less pleasant but quite as effective method was to carry a jar of carrion to the jungle and there unstopper it, and the host which gathered could be numbered by the score of species. Or the body of a red howling monkey, revisited after several days,

would furnish such varied specimens as king and yellow-headed vultures, rare and beautiful butterflies, and giant-horned scarabs all in blue and copper mail.

The sense of sight was resorted to by placing the wings of a metallic morpho in the band of one's helmet, as a miner carries his lighted lamp, when any of these wary butterflies within sight would usually deflect their flight and descend to within easy reach of the net.

A third sense—that of hearing—was a fertile source of profit. The old, old trick of squeaking like a young bird in trouble was as effective in the tropics as elsewhere, more so perhaps, for it never failed to elicit some response from the smaller pugnacious people of the jungle. From an apparently deserted part of the forest I have summoned a noisy flock of many species, coming from nest or food. Even when they arrived within sight, they could not but continue to believe that somewhere there was a friend in trouble and some of the smaller ones would come within a foot or two of my face. After a suspicious bird had given the alarm and all had scattered, a wait of ten minutes would restore a perfect confidence in the deceit.

Much more interesting than any of these artificial methods was to learn the secrets of the jungle and find some outburst of blossoms or wholesale ripening of a treeful of fruit or berries, or the maturing of a harvest of nuts on some forest giant. For these were magnets which drew creatures, often in hundreds, from miles in every direction. A blind built in such a place was well worth occupancy for many hours. Favourite roosting trees were another source of observation and of netting the birds, which lost much of their fear of man as twilight approached. Finally, and most delightful of all, it was a joy to find an occupied nest, such as that of some little jungle manakin, low down in an accessible spot. With this as a localised lure,

a magnet which for a time bound two birds to a single spot in space, one merged oneself as much as might be into the surroundings and keenly watched all the matters of home life which were vouchsafed to the mere outsider.

Only when we encountered such singular creatures as the hoatzins, which, to their peculiar physical and hereditary interests add a static mode of life and habitat which is almost vegetative, do we appreciate the difficulties of finding and keeping under continual observation other more active organisms—cursorial or volant.

A colony of vampires had long been in possession of a hollow under the roof of Kalacoon. We left them undisturbed, for we desired to watch them and learn something of their habits. Their wings swept our faces throughout the night, but they never molested us even when we ceased to keep the vampire lantern alight. We began our campaign for securing young bats by the crude method of waiting with a 22-calibre rifle for them to alight on a favourite spot on the lofty rafters. This resulted in the indiscriminate killing of several, but left us still in complete ignorance as to the young. A second plan was immediately successful and in quite a wholesale way. In the late afternoon we suspended a light net from the outside eaves, so that it hung downward over the entrance to the "battery." In an hour vampires began to fly out and become entangled in the meshes. One after the other we freed and examined them, liberating all but the very young ones. The net was later removed, the colony remained intact, and we had achieved our desires.

These and scores of other tricks of the trade were learned by constant experience. At first all we could do was to walk silently through the underbrush or squat motionless at the foot of some great tree in a

likely looking spot. And even after years of jungle observation I still resort to these two methods again and again. They are the ones where pure luck enters in, and every carefully taken step is a gamble, every passing minute of waiting is filled with expectancy. Silence and apparently lifeless surroundings may be the reward, or suddenly there may be perceived some new strange creature or some unimagined habit. It was while taking shelter from the rain in a great hollow tree on the present expedition that I first saw a tinamou—one of the large species—mounting a slanting tree-trunk. And this was the final proof which was all I wanted to put the seal of certainty upon the careful investigation which I had undertaken.

William Beebe

ASTRONOMY

THE STUDY OF ASTRONOMY

On the evening of January 7, 1610, a fateful day for the human race, Galileo Galilei, Professor of Mathematics in the University of Padua, sat in front of a telescope he had made with his own hands.

More than three centuries previously, Roger Bacon, the inventor of spectacles, had explained how a telescope could be constructed so as " to make the stars appear as near as we please." He had shown how a lens could be so shaped as to collect all the rays of light falling on it from a distant object, bend them until they met in a focus and then pass them on through the pupil of the eye on to the retina. Such an instrument would increase the power of the human eye, just as an ear-trumpet increases the power of the human ear by collecting all the waves of sound which fall on a large aperture, bending them, and passing them through the orifice of the ear on to the ear-drum.

Yet it was not until 1608 that the first telescope had been constructed by Lippershey, a Flemish spectacle-maker. On hearing of this instrument, Galileo had set to work to discover the principles of its construction, and had soon made himself a telescope far better than the original. His instrument had created no small sensation in Italy. Such extraordinary stories had been told of its powers that he had been commanded to take it to Venice to exhibit it to the Doge and the Senate. The citizens of Venice had then seen the most aged of their senators climbing the highest bell-towers to spy through the telescope

at ships which were too far out at sea to be seen at all without its help. The telescope admitted about a hundred times as much light as the unaided human eye, and, according to Galileo, it showed an object at fifty miles as clearly as if it were only five miles away.

The absorbing interest of his new instrument had almost driven from Galileo's mind a problem to which he had at one time given much thought. Over 2000 years previously, Pythagoras and Philolaus had taught that the earth is not fixed in space but rotates on its axis every twenty-four hours, thus causing the alternation of day and night. Aristarchus of Samos, perhaps the greatest of all Greek mathematicians, had further maintained that the earth not only turned on its axis, but also described a yearly journey round the sun, this being the cause of the cycle of the seasons.

Then these doctrines had fallen into disfavour. Aristotle had pronounced against them, asserting that the earth formed a fixed centre to the universe. Later Ptolemy had explained the tracks of the planets across the sky in terms of a complicated system of cycles and epicycles ; the planets moved in circular paths around moving points, which in turn moved in circles round an immovable earth. The Church had given its sanction and active support to these doctrines. Indeed, it is difficult to see what else it could have done, for it seemed almost impious to suppose that the great drama of man's fall and redemption in which the Son of God had Himself taken part could have been enacted on any lesser stage than the very centre of the Universe.

Yet, even in the Church, the doctrine had not gained universal acceptance. Oresme, Bishop of Lisieux, and Cardinal Nicholas of Cusa had both declared against it, the latter writing in 1440 :

" I have long considered that this earth is not fixed,

but moves as do the other stars. To my mind the earth turns upon its axis once every day and night."

At a later date, those who held these views incurred the active hostility of the Church, and in 1600 Giordano Bruno was burned at the stake. He had written :

" It has seemed to me unworthy of the divine goodness and power to create a finite world, when able to produce beside it another and others infinite ; so that I have declared that there are endless particular worlds similar to this of the earth ; with Pythagoras I regard it as a star, and similar to it are the moon, the planets, and other stars which are infinite in number, and all these bodies are worlds."

The most weighty attack on orthodox doctrine had, however, been delivered neither by theologians nor philosophers, but by the Polish astronomer Nicolaus Copernicus (1473–1543). In his great work *De Revolutionibus Orbium Coelestium*, Copernicus had shown that Ptolemy's elaborate structure of cycles and epicycles was unnecessary, because the tracks of the planets across the sky could be explained quite simply by supposing that the earth and the planets all moved round a fixed central sun. The sixty-six years which had elapsed since this book was published had seen these theories hotly debated, but they were still neither proved nor disproved.

Galileo had already found that his new telescope provided a means of testing astronomical theories. As soon as he had turned it on to the Milky Way, a whole crowd of legends and fables as to its nature and structure had vanished into thin air ; it proved to be nothing more than a swarm of faint stars scattered like golden dust on the black background of the sky. Another glance through the telescope had disclosed the true nature of the moon. It had on it mountains which cast shadows, and so proved, as

Giordano Bruno had maintained, to be a world like our own. What if the telescope should now in some way prove able to decide between the orthodox doctrine that the earth formed the hub of the universe, and the new doctrine that the earth was only one of a number of bodies, all circling round the sun like moths round a candle-flame?

And now Galileo catches Jupiter in the field of his telescope and sees four small bodies circling around the great mass of the planet—like moths round a candle-flame. What he sees is an exact replica of the solar system as imagined by Copernicus, and it provides a direct visual proof that such systems are at least not alien to the architectural plan of the universe. And yet, strangely enough, he hardly sees the full implications of his discovery at once; he merely avers that he has discovered four new planets which chase one another round and round the known planet Jupiter.

Final and complete understanding comes nine months later when he observes the phases of Venus. Venus might have been self-luminous, in which case she would always appear as a full circle of light. If she were not self-luminous but moved in a Ptolemaic epicycle, then, as Ptolemy had himself pointed out, she could never show more than half her surface illuminated. On the other hand, the Copernican view of the solar system required that both Venus and Mercury should exhibit "phases" like those of the moon, their shining surfaces ranging in appearance from crescent-shape through half moon to full moon, and then back through half moon to crescent-shape. That such phases were not shown by Venus had indeed been urged as an objection to the Copernican theory.

Galileo's telescope now shows that, as Copernicus had foretold, Venus passes through the full cycle of

phases, so that, in Galileo's own words, we " are now supplied with a determination most conclusive, and appealing to the evidence of our senses," that " Venus, and Mercury also, revolve around the sun, as do also all the rest of the planets, a truth believed indeed by the Pythagorean school, by Copernicus, and by Kepler, but never proved by the evidence of our senses, as is now proved in the case of Venus and Mercury."

These discoveries of Galileo made it clear that Aristotle, Ptolemy, and the majority of those who had thought about these things in the last 2000 years had been utterly and hopelessly wrong. In estimating his position in the universe, man had up to now been guided mainly by his own desires and his self-esteem ; long fed on boundless hopes, he had spurned the simpler fare offered by patient scientific thought. Inexorable facts now dethroned him from his self-arrogated station at the centre of the universe ; henceforth he must reconcile himself to the humble position of the inhabitant of a speck of dust, and adjust his views on the meaning of human life accordingly.

The adjustment was not made at once. Human vanity, reinforced by the authority of the Church, contrived to make a rough road for those who dared draw attention to the earth's insignificant position in the universe. Galileo was forced to abjure his beliefs. Well on into the eighteenth century the ancient University of Paris taught that the motion of the earth round the sun was a convenient *but false* hypothesis, while the newer American Universities of Harvard and Yale taught the Ptolemaic and Copernican systems of astronomy side by side as though they were equally tenable. Yet men could not keep their heads buried in the sands for ever, and when at last its full implications were accepted, the revolution of thought initiated by Galileo's observations of January 7, 1610,

proved to be the most catastrophic in the history of the race. The cataclysm was not confined to the realms of abstract thought ; henceforth human existence itself was to appear in a new light, and human aims and aspirations would be judged from a different standpoint.

This oft-told story has been told once again, in the hope that it may serve to explain some of the interest taken in astronomy to-day. The more mundane sciences prove their worth by adding to the amenities and pleasures of life, or by alleviating pain or distress, but it may well be asked what reward astronomy has to offer. Why does the astonomer devote arduous nights, and still more arduous days, to studying the structure, motions, and changes of bodies so remote that they can have no conceivable influence on human life ?

In part at least the answer would seem to be that many have begun to suspect that the astronomy of to-day, like that of Galileo, may have something to say on the enthralling question of the relation of human life to the universe in which it is placed, and on the beginnings, meaning, and destiny of the human race. Bede records how, some twelve centuries ago, human life was compared in poetic simile to the flight of a bird through a warm hall in which men sit feasting, while the winter storms rage without :

" The bird is safe from the tempest for a brief moment, but immediately passes from winter to winter again. So man's life appears for a while, but of what is to follow, or of what went before, we know nothing. If, therefore, a new doctrine tells us something certain, it seems to deserve to be followed."

These words, originally spoken in advocacy of the Christian religion, describe what is perhaps the main interest of astronomy to-day. Man " only knowing Life's little lantern between dark and dark," wishes

to probe further into the past and future than his brief span of life permits. He wishes to see the universe as it existed before man was, as it will be after the last man has passed again into the darkness from which he came. The wish does not originate solely in mere intellectual curiosity, in the desire to see over the next range of mountains, the desire to attain a summit commanding a wide view, even if it be only of a promised land which he may never hope himself to enter ; it has deeper roots and a more personal interest. Before he can understand himself, man must first understand the universe from which all his sense perceptions are drawn. He wishes to explore the universe, both in space and time, because he himself forms part of it, and it forms part of him.

We may well admit that science cannot at present hope to say anything final on the questions of human existence and human destiny, but this is no justification for not becoming acquainted with the best that it has to offer. It is rare indeed for science to give a final " Yes " or " No " answer to any question propounded to her. When we are able to put a question in such a definite form that either of these answers could be given in reply, we are generally already in a position to supply the answer ourselves. Science advances rather by providing a succession of approximations to the truth, each more accurate than the last, but each capable of endless degrees of higher accuracy. To the question, " Where does man stand in the universe ? " the first attempt at an answer, at any rate in recent times, was provided by the astronomy of Ptolemy : " At the centre." Galileo's telescope provided the next, and incomparably better, approximation : " Man's home in space is only one of a number of small bodies revolving round a huge central sun." Nineteenth-century astronomy swung the pendulum still further in the same direction, say-

ing : " There are millions of stars in the sky, each similar to our sun, each doubtless surrounded, like our sun, by a family of planets on which life may be kept in being by the light and heat received from its sun." Twentieth-century astronomy suggests, as we shall see, that the nineteenth century had swung the pendulum; life now seems to be more of a rarity than our fathers thought, or would have thought if they had given free play to their intellects.

We are setting out to explain the approximation to the truth provided by twentieth-century astronomy. No doubt it is not the final truth, but it is a step on towards it, and unless we are greatly in error it is very much nearer to the truth, not because the twentieth-century astronomer claims to be better at guessing than his predecessors of the nineteenth century, but because he has incomparably more facts at his disposal. Guessing has gone out of fashion in science ; it was at best a poor substitute for knowledge, and modern science, eschewing guessing severely, confines itself, except on very rare occasions, to ascertained facts, and the inferences which, so far as can be seen, follow unequivocally from them.

It would of course be futile to pretend that the whole interest of astronomy centres round the questions just mentioned. Astronomy offers at least three other groups of interests which may be described as utilitarian, scientific, and aesthetic.

At first astronomy, like other sciences, was studied mainly for utilitarian interests. It provided measures, and enabled mankind to keep a tally on the flight of the seasons ; it taught him to find his way across the trackless desert, and later across the trackless ocean. In the guise of astrology, it held out hopes of telling him its future. There was nothing intrinsically absurd in this, for even to-day the astronomer is largely occupied with telling the future movements

of the heavenly bodies, although not of human affairs—a considerable part of the present book will consist of an attempt to foretell the future, and predict the final end, of the material universe. Where the astrologers went wrong was in supposing that terrestial empires, kings, and individuals formed such important items in the scheme of the universe that the motions of the heavenly bodies could be intimately bound up with their fates. As soon as man began to realise, even faintly, his own significance in the universe astrology died a natural and inevitable death.

The utilitarian aspect of astronomy has by now shrunk to very modest proportions. The national observatories still broadcast the time of day, and help to guide ships across the ocean, but the centre of astronomical interest has shifted so completely that the remotest of nebulae arouse incomparably more enthusiasm than "clock-stars," and the average astronomer totally neglects our nearest neighbours in space, the planets, for stars so distant that their light takes hundreds, thousands, or even millions of years to reach us.

Recently, astronomy has acquired a new scientific interest through establishing its position as an integral part of the general body of science. The various sciences can no longer be treated as distinct ; scientific discovery advances along a continuous front which extends unbroken from electrons of a fraction of a millionth of a millionth of an inch in diameter, to nebulae whose diameters are measured in hundreds of thousands of millions of millions of miles. A gain of astronomical knowledge may add to our knowledge of physics and chemistry and *vice versa*. The stars have long ago ceased to be treated as mere points of light. Each is now regarded as an experiment on the heroic scale, a high temperature and pressure far beyond those available in our laboratories, and per-

mits us to watch the results. In so doing, we may happen upon properties of matter which have eluded the terrestial physicist, owing to the small range of physical conditions at his command.

For instance, matter exists in nebulae with a density at least a million times lower than anything we can approach on earth, and in certain stars at a density nearly a million times greater. How can we expect to understand the whole nature of matter from laboratory experiments in which we can command only one part in a million million of the whole range of density known to nature?

Yet for each one who feels the purely scientific appeal of astronomy, there are probably a dozen who are attracted by its aesthetic appeal. Many even of those who seek after knowledge for its own sake, driven by that intellectual curiosity which provides the fundamental distinction between themselves and the beasts, find their main interest in astronomy, as the most poetical and the most aesthetically gratifying of the sciences. They want to exercise their faculties and imaginations on something remote from everyday trivialities, to find an occasional respite from "the long littleness of life," and they satisfy their desires in contemplating the serene immensities of the outer universe. To many, astronomy provides something of the vision without which the people perish.

Before proceeding to describe the results of the modern astronomers' survey of the sky, let us try to envisage in its proper perspective the platform from which his observations are made.

Later on, we shall see how the earth was born out of the sun, something like 2000 millions of years ago. It was born in the form in which we should find it hard to recognise the solid earth of to-day with its seas and rivers, its rich vegetation and overflowing life. Our home in space came into being as a globe

of intensely hot gas in which no life of any kind could either gain or retain a foothold.

Gradually this globe of gas cools down, becoming first liquid, then plastic. Finally its outer crust solidifies, rocks and mountains forming a permanent record of the irregularities of its earlier plastic form. Vapours condense into liquids, and rivers and oceans come into being, while the " permanent " gases form an atmosphere. Gradually the earth assumes a condition suited to the advent of life, which finally appears, we know not how, whence, or why.

It is not easy to estimate the time since life first appeared on earth, but it can hardly have been more than a small fraction of the whole 2000 million years of the earth's existence. Still, there was life on earth at least 300 million years ago. The first life appears to have been wholly aquatic, but gradually fishes changed into reptiles, reptiles into mammals, and finally man emerged from mammals. The evidence favours a period of about 300,000 years ago for this last event. Thus life has inhabited the earth for only a fraction of its existence, and man for only a tiny fraction of this fraction. To put it in another way, the astronomical time-scale is incomparably longer than the human time-scale—the generations of man, and even the whole of human existence, are only ticks of the astronomer's clock.

Most of the 10,000 or so of generations of men who connect us up with our ape-like ancestry must have lived lives which did not differ greatly from those of their animal predecessors. Hunting, fishing, and warfare filled their lives, leaving but little time or opportunity for intellectual contemplation. Then, at last, man began to wake from his long intellectual slumber, and, as civilisation slowly dawned, to feel the need for occupations other than the mere feeding and clothing of his body. He began to discover revelations

of infinite beauty in the grace of the human form or the play of light on the myriad-smiling sea, which he tried to perpetuate in carefully chiselled marble or exquisitely chosen words. He began to experiment with metals and herbs, and with the effects of fire and water. He began to notice, and try to understand, the motions of the heavenly bodies, for to those who could read the writing in the sky, the nightly rising and setting of the stars and planets provided evidence that beyond the confines of the earth lay an unknown universe built on a far grander scale.

In this way the arts and sciences came to the earth, bringing astronomy with them. We cannot quite say when, but compared even with the age of the human race, they came but yesterday, while in comparison with the whole age of the earth, their age is but a twinkling of an eye.

Scientific astronomy, as distinguished from mere star-gazing, can hardly claim an age of more than 3000 years. It is less than this since Pythagoras, Aristarchus, and others explained that the earth moved round a fixed sun. Yet the really significant figure for our present purpose is not so much the time since men began to make conjectures about the structure of the universe, as the time since they began to unravel its true structure by the help of ascertained fact. The important length of time is that which has elapsed since that evening in 1610 when Galileo first turned his telescope on Jupiter—a mere three centuries or so.

We begin to grasp the true significance of these round-number estimates when we rewrite them in tabular form. We have :—

Age of earth . .	About	2,000,000,000	years
Age of life on earth .	,,	300,000,000	,,
Age of man on earth .	,,	300,000	,,

Age of astronomical science	.	About 3,000 years
Age of telescopic astronomy	.	,, 300 ,,

When the various figures are displayed in this form, we see what a very recent phenomenon astronomy is. Its total age is only a hundredth part of the age of man, only a hundred-thousandth part of the time that life has inhabited the earth. During 99,999 parts out of the 100,000 of its existence, life on earth was hardly concerned about anything beyond the earth. But whereas the past of astronomy is to be measured on the human time-scale, a hundred generations or so of men, there is every reason to expect that its future will be measured on the astronomical time-scale. We shall discuss the probable future stretching before the human race in a later chapter. For the moment it is not unreasonable to suppose that this future will probably be terminated by astronomical causes, so that its length is to be measured on the astronomical time-scale. As the earth has already existed for 2000 million years, yet it is *a priori* reasonable to suppose that it will exist for at least something in the order of 2000 million years yet to come, and humanity and astronomy with it. Actually we shall find reasons for expecting it to last for longer than this. But if once it is conceded that its future life is to be estimated on the astronomical time-scale, no matter in what exact way, we see that astronomy is still at the very opening of its existence. This is why its message can claim no finality—we are not describing the mature convictions of a man so much as the first impressions of a newborn babe which is just opening its eyes. Even so they are better than the idle introspective dreamings in which it indulged before it had learned to look around itself and away from itself.

And so we set out to learn what astronomy has to

tell us about the universe in which we live our lives. Our inquiry will not be entirely limited to this one science. We shall call upon other sciences, physics, chemistry, and geology, as well as the more closely allied sciences of astrophysics and cosmogony, to give help when they can in interpreting the message of observational astronomy. The information we shall obtain will be fragmentary. If it must be compared to anything, let it be to the pieces of a jig-saw puzzle. Could we get hold of all the pieces, they would, we are confident, form a single, complete, consistent picture, but many of them are still missing. It is too much to hope that the incomplete series of pieces we have already found will disclose the whole picture, but we may at least collect them together, arrange them in some sort of methodical order, fit together pieces which are obviously contiguous, and perhaps hazard a guess as to what the finished picture will prove to be when all its pieces have been found and finally fitted together.

SIR JAMES JEANS

MAN'S PLACE IN THE UNIVERSE

THE largest telescopes reveal about 1000 million stars. Each increase in telescopic power adds to the number and we can scarcely set a limit to the multitude that must exist. Nevertheless, there are signs of exhaustion and it is clear that the distribution which surrounds us does not extend uniformly through infinite space. At first an increase in light-grasp by one magnitude brings into view three times as many stars ; but the factor diminishes, so that at the limit of faintness reached by the giant telescopes a gain of one magnitude multiplies the number of stars seen

by only 1·8, and the ratio at that stage is rapidly decreasing. It is as though we were approaching a limit at which increase of power will not bring into view very many additional stars.

Attempts have been made to find the whole number of stars by a risky extrapolation of these counts, and totals ranging from 3000 to 30,000 millions are sometimes quoted. But the difficulty is that the part of the stellar universe which we mainly survey is a local condensation or star-cloud forming part of a much greater system. In certain directions in the sky our telescopes penetrate to the limits of the system, but in other directions the extent is too great for us to fathom. The Milky Way, which on a dark night forms a gleaming belt round the sky, shows the direction in which there lie stars behind stars until vision fails. This great flattened distribution is called the Galactic System. It forms a disc of thickness small compared with its areal extent. It is partly broken up into subordinate condensations which are probably coiled in spiral form like the spiral nebulae which are observed in great numbers in the heavens. The centre of the galactic system lies somewhere in the direction of the constellation Sagittarius ; it is hidden from us not only by great distance but by tracts of obscuring matter (dark nebulosity) which cuts off the light of the stars behind.

We must distinguish, then, between our local star-cloud and the great galactic system of which it is a part. Mainly (but not exclusively) the star counts relate to the local star-cloud, and it is this which the largest telescopes are beginning to exhaust. It too has a flattened form—flattened nearly in the same plane as the galactic system. If the galactic system is compared to a disc, the local star-cloud may be compared to a bun, its thickness being about one-third of its lateral extension. Its size is such that light

takes at least 2000 years to travel from one side to the other: this measurement is necessarily rough because it relates to a vague condensation which is probably not sharply separated from other contiguous condensations. The extent of the whole spiral is of the nature 100,000 years. It can scarcely be doubted that the flattened form of the system is due to rapid rotation, and indeed there is direct evidence of strong rotational velocity; but it is one of the unexplained mysteries of evolution that nearly all the celestial bodies have come to be endowed with fast rotation.

Amid this great population the sun is a humble unit. It is a very ordinary star about midway in the scale of brilliancy. We know of stars which give at least 10,000 times the light of the sun; we know also of stars which give $\frac{1}{10,000}$ of its light. But those of inferior light greatly outnumber those of superior light. In mass, in surface temperature, in bulk, the sun belongs to a very common class of stars; its speed of motion is near the average; it shows none of the more conspicuous phenomena such as variability which excite the attention of astronomers. In the community of stars the sun corresponds to a respectable middle-class citizen. It happens to be quite near the centre of the local star-cloud; but this apparently favoured position is discounted by the fact that the star-cloud itself is placed very eccentrically in relation to the galactic system, being in fact near the confines of it. We cannot claim to be at the hub of the universe.

The contemplation of the galaxy impresses us with the insignificance of our own little world; but we have to go still lower in the valley of humiliation. The galactic system is one among a million or more spiral nebulae. There seems now to be no doubt that, as has long been suspected, the spiral nebulae are "island universes" detached from our own. They

too are great systems of stars—or systems in the process of developing into stars—built on the same disc-like plan. We see some of them edgeways and can appreciate the flatness of the disc ; others are broadside on and show the arrangement of the condensations in the form of a double spiral. Many show the effects of dark nebulosity breaking into the regularity and blotting out the starlight. In a few of the nearest spirals it is possible to detect the brightest of the stars individually ; variable stars and novae (or "new stars") are observed as in our own system. From the apparent magnitudes of the stars of recognisable character (especially the Cepheid variables) it is possible to judge the distance. The nearest spiral nebula is 850,000 light years away.

From the small amount of data yet collected it would seem that our own nebula or galactic system is exceptionally large ; it is even suggested that if the spiral nebulae are "islands" the galactic system is a "continent." But we can scarcely venture to claim premier rank without much stronger evidence. At all events these other universes are aggregations of the order of 100 million stars.

Again the question raises itself, How far does this distribution extend ? Not the stars this time, but universes stretch one behind the other beyond sight. Does this distribution too come to an end ? It may be that imagination must take another leap, envisaging super-systems which surpass the spiral nebulae as the spiral nebulae surpass the stars. But there is one feeble gleam of evidence that perhaps this time the summit of the hierarchy has been reached, and that the system of the spirals is actually the whole world. As has already been explained, the modern view is that space is finite—finite though unbounded. In such a space light which has travelled an appreciable part of the way "round the world" is slowed down

in its vibrations, with the result that all spectral lines are displaced towards the red. Ordinarily we interpret such a red displacement as signifying receding velocity in the line of sight. Now it is a striking fact that a great majority of the spirals which have been measured show large receding velocities often exceeding 1000 kilometres per second. There are only two serious exceptions and these are the largest spirals, which must be nearer to us than most of the others. On ordinary grounds it would be difficult to explain why these other universes should hurry away from us so fast and so unanimously. Why should they shun us like a plague? But the phenomenon is intelligible if what has really been observed is the slowing down of vibrations consequent on the light from these objects having travelled an appreciable part of the way round the world. On that theory the radius of space is of the order twenty times the average distance of the nebulae observed, or, say, 100 million light years. That leaves room for a few million spirals; but there is nothing beyond. There is no beyond—in spherical space "beyond" brings us back towards the earth from the opposite direction.

The Scale of Time.—The corridor of time stretches back through the past. We can have no conception how it all began. But at some stage we imagine the void to have been filled with matter rarefied beyond the most tenuous nebula. The atoms sparsely strewn move hither and thither in formless disorder:

> "Behold the throne
> Of Chaos and his dark Pavilion spread
> Wide on the wasteful deep."

Then slowly the power of gravitation is felt. Centres of condensation begin to establish themselves and draw in other matter. The first partitions are the star-systems such as our galactic system; sub-

condensations separate the star-clouds or clusters; these divide again to give the stars.

Evolution has not reached the same development in all parts. We observe nebulae and clusters in different stages of advance. Some stars are still highly diffuse; others are concentrated like the sun with density greater than water; others, still more advanced, have shrunk to unimaginable density. But no doubt can be entertained that the genesis of the stars are single processes of evolution which has passed and is passing over a primordial distribution. Formerly it was freely speculated that the birth of a star was an individual event like the birth of an animal. From time to time two long-extinct stars would collide and be turned into vapour by the energy of the collision; condensation would follow and life as a luminous body would begin all over again. We can scarcely affirm that this will never occur and that the sun is not destined to have a second or third innings; but it is clear from the various relations traced among the stars that the present stage of existence of the sidereal universe is the "first innings." Groups of stars are found which move across the sky with common proper motion; these must have had a single origin and cannot have been formed by casual collisions. Another abandoned speculation is that lucid stars may be the exception and that there may exist thousands of dead stars for every one that is seen shining. There are ways of estimating the total mass in interstellar space by its gravitational effect on the average speed of the stars; it is found that the lucid stars account for something approaching the total mass admissible and the amount left over for dark stars is very limited.

Biologists and geologists carry back the history of the earth some 1000 million years. Physical evidence based on the rate of transmutation of radio-active

substances seems to leave no escape from the conclusion that the older (Archaean) rocks in the earth's crust were laid down 1200 million years ago. The sun must have been burning still longer, living (we now think) on its own matter which dissolves bit by bit into radiation. According to the theoretical time-scale, which seems best supported by astronomical evidence, the beginning of the sun as a luminous star must be dated five billion ($5 \cdot 10^{12}$) years ago. The theory which assigns this date cannot be trusted confidently, but it seems a reasonably safe conclusion that the sun's age does not exceed this limit. The future is not so restricted and the sun may continue as a star of increasing feebleness for 50 or 500 billion years. The theory of sub-atomic energy has prolonged the life of a star from millions to billions of years, and we may speculate on processes of rejuvenescence which might prolong the existence of the sidereal universe from billions to trillions of years. But unless we can circumvent the second law of thermo-dynamics—which is as much as to say unless we can find cause for time to run backwards—the ultimate decay draws surely nearer and the world will at the last come to a state of uniform changelessness.

Does this prodigality of matter, of space, of time, find its culmination in Man?

Plurality of Worlds.—I will here put together the present astronomical evidence as to the habitability of other worlds. The popular idea that an answer to this question is one of the main aims of the study of celestial objects is rather disconcerting to the astronomer. Anything that he has to contribute is of the nature of fragmentary hints picked up in the course of investigations with more practicable and commonplace purposes. Nevertheless, the mind is irresistibly drawn to play with the thought that somewhere in the universe there may be other beings "a

little lower than the angels " whom Man may regard as his equals—or perhaps his superiors.

It is idle to guess the forms of life in conditions differing from those of our planet. If I have rightly understood the view of palaeontologists, mammalian life is the third terrestial dynasty—Nature's third attempt to evolve an order of life sufficiently flexible to changing conditions and fitted to dominate the earth. Minor details in the balance of circumstances must greatly affect the possibility of life and the type of organism destined to prevail. Some critical branch-point in the course of evolution must be negotiated before life can rise to the level of consciousness. All this is remote from the astronomer's line of study. To avoid endless conjecture, I shall assume that the required conditions of habitability are not unlike those on the earth, and that if such conditions obtain life will automatically make its appearance.

We survey first the planets of the solar system ; of these only Venus and Mars seem at all eligible. Venus, so far as we know, would be well adapted for life similar to ours. It is about the same size as the earth, nearer the sun but probably not warmer, and it possesses an atmosphere of satisfactory density. Spectroscopic observation has unexpectedly failed to give any indication of oxygen in the upper atmosphere of satisfactory density, and thus suggests a doubt as to whether free oxygen exists on the planet ; but at present we hesitate to draw so definite an inference. If transplanted to Venus, we might perhaps continue to live without much derangement of habit—except that I personally would have to find a new profession, since Venus is not a good place for astronomers. It is completely covered with cloud or mist. For this reason no definite surface markings can be made out, and it is still uncertain how fast it rotates on its axis and in which direction the axis lies. One curious

theory may be mentioned though it should perhaps not be taken too seriously. It is thought by some that the great cavity occupied by the Pacific Ocean is a scar left by the moon when it was first disrupted from the earth. Evidently this cavity fulfils an important function in draining away superfluous water and if it were filled up practically all the continental area would be submerged. Thus indirectly the existence of dry land is bound up with the existence of the moon. But Venus has no moon, and since it seems to be similar to the earth in other respects, it may perhaps be inferred that it is a world which is all ocean—where fishes are supreme. The suggestion at any rate serves to remind us that the destinies of organic life may be determined by what are at first sight irrelevant accidents.

The sun is an ordinary star and the earth is an ordinary planet, but the moon is not an ordinary satellite. No other known satellite is anything like so large in proportion to the planet which it attends. The moon contains about $\frac{1}{80}$ part of the mass of the earth, which seems a small ratio; but it is abnormally great compared with other satellites. The next highest ratio is found in the system of Saturn, whose largest satellite, Titan, has $\frac{1}{4000}$ of the planet's mass. Very special circumstances must have occurred in the history of the earth to have led to the breaking away of so unusual a fraction of the mass. The explanation proposed by Sir George Darwin, which is still regarded as most probable, is that a resonance in period occurred between the solar tides and the natural free period of vibration of the globe of the earth. The tidal deformation of the earth thus grew to large amplitude ending in a cataclysm which separated the great lump of material that formed the moon. Other planets escaped this dangerous coincidence of period, and their satellites separated by mere normal

development. If ever I meet a being who has lived in another world, I shall feel very humble in most respects, but I expect to be able to boast a little about the moon.

Mars is the only planet whose solid surface can be seen and studied and it tempts us to consider the possibility of life in more detail. Its smaller size leads to considerably different conditions ; but the two essentials, air and water, are both present though scanty. The Martian atmosphere is thinner than our own but it is perhaps adequate. It has been proved to contain oxygen. There is no ocean ; the surface markings represent, not sea and land, but red desert and darker ground which is perhaps moist and fertile. A conspicuous feature is the white cap covering the pole, which is clearly a deposit of snow ; it must be quite shallow since it melts away completely in the summer. Photographs show from time to time indubitable clouds which blot out temporarily large areas of surface detail ; clear weather, however, is more usual. The air, if cloudless, is slightly hazy. W. H. Wright has shown this very convincingly by comparing photographs taken with light of different wave-lengths. Light of short wave-length is much scattered by haze and accordingly the ordinary photographs are disappointingly blurry. Much sharper surface-detail is shown when visual yellow light is employed (a yellow screen being commonly used to adapt visual telescopes for photography) ; being of longer wave-length, the visual rays penetrate the haze more easily.

Still clearer detail is obtained by photographing with the long infra-red waves.

Great attention has lately been paid to the determination of the temperature of the surface of Mars ; it is possible to find this by direct measurement of the heat radiated to us from different parts of the surface.

The results, though in many respects informative, are scarcely accurate and accordant enough to give a definite idea of the climatology. Naturally the temperature varies a great deal between day and night and in different latitudes ; but on the average the conditions are decidedly chilly. Even at the equator the temperature falls below freezing-point at sunset. If we accepted the present determinations as definitive, we should have some doubt as to whether life could endure the conditions.

In one of Huxley's Essays there occurs the passage "Until human life is longer and the duties of the present press less heavily I do not think that wise men will occupy themselves with Jovian or Martian natural history." To-day it would seem that Martian natural history is not altogether beyond the limits of serious science.

At least the surface of Mars shows a seasonal change such as we might well imagine the forest-clad earth would show to an outside onlooker. This seasonal change of appearance is very conspicuous to the attentive observer. As the spring in one hemisphere advances (I mean, of course, the Martian spring), the darker areas, which are at first few and faint, extend and deepen in contrast. The same regions darken year after year at nearly the same date in the Martian calendar. It may be that there is an inorganic explanation ; the spring rains moisten the surface and change its colour. But it is perhaps unlikely that there is enough rain to bring about this change as a direct effect. It is easier to believe that we are witnessing the annual awakening of vegetation so familiar on our own planet.

The existence of oxygen in the Martian atmosphere supplies another argument in support of the existence of vegetable life. Oxygen combines freely with many elements, and the rocks in the earth's crust are thirsty

for oxygen. They would in course of time bring about its complete disappearance from the air, were it not that the vegetation extracts it from the soil and sets it free again. If oxygen in the terrestrial atmosphere is maintained in this way, it would seem reasonable to assume that vegetable life is required to play the same part on Mars. Taking this in conjunction with the evidence of the seasonal changes of appearance, a rather strong case for the existence of vegetation seems to have been made out.

If vegetable life must be admitted, can we exclude animal life ? I have come to the end of the astronomical data and can take no responsibility for anything further that you may infer. It is true that the late Prof. Lowell argued that certain more or less straight markings on the planet represent an artificial irrigation system and the signs of an advanced civilisation ; but this theory has not, I think, won much support. In justice to the author of this speculation it should be said that his own work and that of his observatory have made a magnificent contribution to our knowledge of Mars ; but few would follow him all the way on the most picturesque side of his conclusions.* Finally, we may stress one point. Mars has every appearance of being a planet long past its prime ; and it is in any case improbable that two planets differing so much as Mars and the Earth would be in the zenith of biological development contemporaneously.

Formation of Planetary Systems.—If the planets of the solar system should fail us, there remain some thousands of millions of stars which we have been accustomed to regard as suns ruling attendant systems of

* *Mars is not seen under favourable conditions except from low latitudes and high altitudes. Astronomers who have not these advantages are reluctant to form a decided opinion on the many controversial points that have arisen.*

planets. It has seemed a presumption, bordering almost on impiety, to deny to them life of the same order of creation as ourselves. It would indeed be rash to assume that nowhere else in the universe has Nature repeated the strange experiment which she has performed on the earth. But there are considerations which must hold us back from populating the universe too liberally. On examining the stars with a telescope we are surprised to find how many of those which appear single points to the eye are actually two stars close together. When the telescope fails to separate them the spectroscope often reveals two stars in orbital revolution round each other. At least one star in three is double—a pair of self-luminous globes both comparable in dimensions with the sun. The single supreme sun is accordingly not the only product of evolution ; not much less frequently the development has taken another turn and resulted in two suns closely associated. We may probably rule out the possibility of planets in double stars. Not only is there a difficulty in ascribing to them permanent orbits under the more complicated field of gravitation, but a cause for the formation of planets seems to be lacking. The star has satisfied its impulse to fission in another manner ; it has divided into two nearly equal portions instead of throwing off a succession of tiny fragments.

The most obvious cause of division is excessive rotation. As the gaseous globe contracts it spins faster and faster until a time may come when it can no longer hold together, and some kind of relief must be found. According to the nebular hypothesis of Laplace, the sun gained relief by throwing off successively rings of matter which have formed the planets. But were it not for this one instance of a planetary system which is known to us, we should have concluded from the thousands of double stars in the sky

that the common consequence of excessive rotation is to divide the star into two bodies of equal rank.

It might still be held that the ejection of a planetary system and the fission into a double star are alternative solutions of the problem arising from excessive rotation, the star taking one course or the other according to circumstances. We know of myriads of double stars and of only one planetary system ; but in any case it is beyond our power to detect other planetary systems if they exist. We can only appeal to the results of theoretical study of rotating masses of gas ; the work presents many complications and the results may not be final ; but the researches of Sir J. H. Jeans lead to the conclusion that rotational break-up produces a double star and never a system of planets. The solar system is not the typical product of development of a star ; it is not even a common variety of development : it is a freak.

By elimination of alternatives it appears that a configuration resembling the solar system would only be formed if at a certain stage of condensation an unusual accident had occurred. According to Jeans, the accident was the close approach of another star casually pursuing its way through space. This star must have passed within a distance not far outside the orbit of Neptune ; it must not have passed too rapidly, but have slowly overtaken or been overtaken by the sun. By tidal distortion it raised big protuberances on the sun, and caused it to spurt out filaments of matter which have condensed to form the planets. That was more than a thousand million years ago. The intruding star has since gone on its way and mingled with the others ; its legacy of a system of planets remains, including a globe habitable by man.

Even in the long life of a star encounters of this kind must be extremely rare. The density of distribution of stars in space has been compared to that of twenty

tennis-balls roaming the whole interior of the earth. The accident that gave birth to the solar system may be compared to the casual approach of two of these balls within a few yards of one another. The data are too vague to give any definite estimate of the odds against this occurrence, but I should judge that perhaps not one in a hundred million stars can have undergone this experience in the right stage and conditions to result in the formation of a system of planets.

However doubtful this conclusion as to the rarity of solar systems may be, it is a useful corrective to the view too facilely adopted which looks upon every star as a likely minister to life. We know the prodigality of Nature. How many acorns are scattered for one that grows to an oak? And need she be more careful of her stars than of her acorns? If indeed she has no grander aim than to provide a home for her greatest experiment, Man, it would be just like her methods to scatter a million stars whereof one might haply achieve her purpose.

The number of possible abodes of life severely restricted in this way at the outset may no doubt be winnowed down further. On our house-hunting expedition we shall find it necessary to reject many apparently eligible mansions on points of detail. Trivial circumstances may decide whether organic forms originate at all; further conditions may decide whether life ascends to a complexity like ours or remains in a lower form. I presume, however, that at the end of the weeding out there will be left a few rival earths dotted here and there about the universe.

A further point arises if we have specially in mind contemporaneous life. The time during which man has been on earth is extremely small compared with the age of the earth or of the sun. There is no obvious physical reason why, having once arrived, man should not continue to populate the earth for another ten

billion years or so ; but—well, can you contemplate it ? Assuming that the stage of highly-developed life is a very small fraction of the inorganic history of the star, the rival earths are in general places where conscious life has already vanished or is yet to come. I do not think that the whole purpose of the Creation has been staked on the one planet where we live ; and in the long run we cannot deem ourselves the only race that has been or will be gifted with the mystery of consciousness. But I feel inclined to claim that *at the present time* our race is supreme ; and not one of the profusion of stars in their myriad clusters looks down on scenes comparable to those which are passing beneath the rays of the sun.

SIR A. S. EDDINGTON

PHYSICS

RELATIVITY

Let us suppose our old friend the railway carriage to be travelling along the rails with a constant velocity v, and that a man traverses the length of the carriage in the direction of travel with a velocity w. How quickly or, in other words, with what velocity W does the man advance relative to the embankment during the process? The only possible answer seems to result from the following consideration: If the man were to stand still for a second, he would advance relative to the embankment through a distance v equal numerically to the velocity of the carriage. As a consequence of his walking, however, he traverses an additional distance w relative to the carriage, and hence also relative to the embankment, in this second, the distance w being numerically equal to the velocity with which he is walking. Thus in total he covers the distance $W = v + w$ relative to the embankment in the second considered. We shall see later that this result, which expresses the theorem of the addition of velocities employed in classical mechanics, cannot be maintained; in other words, the law that we have just written down does not hold in reality. For the time being, however, we shall assume its correctness.

There is hardly a simpler law in physics than that according to which light is propagated in empty space. Every child at school knows, or believes he knows, that this propagation takes place in straight lines with a velocity $c = 300{,}000$ km./sec. At all events we know

with great exactness that this velocity is the same for all colours, because if this were not the case, the minimum of emission would not be observed simultaneously for different colours during the eclipse of a fixed star by its dark neighbour. By means of similar considerations based on observations of double stars, the Dutch astronomer De Sitter was also able to show that the velocity of propagation of light cannot depend on the velocity of motion of the body emitting the light. The assumption that this velocity of propagation is dependent on the direction " in space " is in itself improbable.

In short, let us assume that the simple law of the constancy of the velocity of light c (in vacuum) is justifiably believed by the child at school. Who would imagine that this simple law has plunged the conscientiously thoughtful physicist into the greatest intellectual difficulties ? Let us consider how these difficulties arise.

Of course we must refer the process of the propagation of light (and indeed every other process) to a rigid reference-body (co-ordinate system). As such a system let us again choose our embankment. We shall imagine the air above it to have been removed. If a ray of light be sent along the embankment, we see from the above that the tip of the ray will be transmitted with the velocity c relative to the embankment. Now let us suppose that our railway carriage is again travelling along the railway lines with the velocity v, and that its direction is the same as that of the ray of light, but its velocity of course much less. Let us inquire about the velocity of propagation of the ray of light relative to the carriage. It is obvious that we can here apply the consideration of the previous section, since the ray of light plays the part of the man walking along relatively to the carriage. The velocity W of the man relative to the embankment is here re-

placed by the velocity of light relative to the embankment. w is the required velocity of light with respect to the carriage, and we have

$$w = c - v.$$

The velocity of propagation of a ray of light relative to the carriage thus comes out smaller than c.

But, like every other general law of Nature, the law of the transmission of light *in vacuo* must, according to the principle of relativity, be the same for the railway carriage as reference-body as when the rails are the body of reference. But, from our above consideration, this would appear to be impossible. If every ray of light is propagated relative to the embankment with the velocity c, then for this reason it would appear that another law of propagation of light must necessarily hold with respect to the carriage—a result contradictory to the principle of relativity.

In view of this dilemma there appears to be nothing else for it than to abandon either the principle of relativity or the simple law of the propagation of light *in vacuo*. Those of you who have carefully followed the preceding discussion are almost sure to expect that we should retain the principle of relativity, which appeals so convincingly to the intellect because it is so natural and simple. The law of the propagation of light *in vacuo* would then have to be replaced by a more complicated law conformable to the principle of relativity. The development of theoretical physics shows, however, that we cannot pursue this course. The epoch-making theoretical investigations of H. A. Lorentz on the electrodynamical and optical phenomena connected with moving bodies show that experience in this domain leads conclusively to a theory of electromagnetic phenomena, of which the law of the constancy of the velocity of light *in vacuo* is a necessary consequence. Prominent theoretical physicists were

therefore more inclined to reject the principle of relativity, in spite of the fact that no empirical data had been found which were contradictory to this principle.

At this juncture the theory of relativity entered the arena. As a result of an analysis of the physical conceptions of time and space, it became evident that *in reality there is not the least incompatibility between the principle of relativity and the law of propagation of light*, and that by systematically holding fast to both these laws a logically rigid theory could be arrived at. This theory has been called the *special theory of relativity* to distinguish it from the extended theory, with which we shall deal later. In the following pages we shall present the fundamental ideas of the special theory of relativity.

•

Lightning has struck the rails on our railway embankment at two places *A* and *B* far distant from each other. I make the additional assertion that these two lightning flashes occurred simultaneously. If I ask you whether there is sense in this statement, you will answer my question with a decided " Yes." But if I now approach you with the request to explain to me the sense of the statement more precisely, you find after some consideration that the answer to this question is not so easy as it appears at first sight.

After some time perhaps the following answer would occur to you : " The significance of the statement is clear in itself and needs no further explanation ; of course it would require some consideration if I were to be commissioned to determine by observations whether in the actual case the two events took place simultaneously or not." I cannot be satisfied with this answer for the following reason. Supposing that as a result of ingenious considerations an able meteorologist were to discover that the lightning must always

strike the places A and B simultaneously, then we should be faced with the task of testing whether or not this theoretical result is in accordance with the reality. We encounter the same difficulty with all physical statements in which the conception "simultaneous" plays a part. The concept does not exist for the physicist until he has the possibility of discovering whether or not it is fulfilled in an actual case. We thus require a definition of simultaneity such that this definition supplies us with the method by means of which, in the present case, he can decide by experiment whether or not both the lightning strokes occurred simultaneously. As long as this requirement is not satisfied, I allow myself to be deceived as a physicist (and of course the same applies if I am not a physicist), when I imagine that I am able to attach a meaning to the statement of simultaneity. (I would ask the reader not to proceed farther until he is fully convinced on this point.)

After thinking the matter over for some time you then offer the following suggestion with which to test simultaneity. By measuring along the rails, the connecting line AB should be measured up and an observer placed at the mid-point M of the distance AB. This observer should be supplied with an arrangement (*e.g.* two mirrors inclined at 90°) which allows him visually to observe both places A and B at the same time. If the observer perceives the two flashes of lightning at the same time, then they are simultaneous.

I am very pleased with this suggestion, but for all that I cannot regard the matter as quite settled, because I feel constrained to raise the following objection: "Your definition would certainly be right, if I only knew that the light by means of which the observer at M perceives the lightning flashes travels along the length $A \longrightarrow M$ with the same velocity as

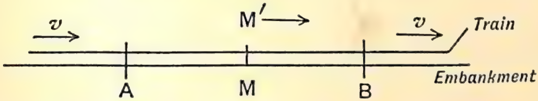
along the length $B \longrightarrow M$. But an examination of this supposition would only be possible if we already had at our disposal the means of measuring time. It would thus appear as though we were moving here in a logical circle."

After further consideration you cast a somewhat disdainful glance at me—and rightly so—and you declare: "I maintain my previous definition nevertheless, because in reality it assumes absolutely nothing about light. There is only *one* demand to be made of the definition of simultaneity, namely, that in every real case it must supply us with an empirical decision as to whether or not the conception that has to be defined is fulfilled. That my definition satisfies this demand is indisputable. That light requires the same time to traverse the path $A \longrightarrow M$ as for the path $B \longrightarrow M$ is in reality neither a *supposition nor a hypothesis* about the physical nature of light, but a *stipulation* which I can make of my own free will in order to arrive at a definition of simultaneity."

It is clear that this definition can be used to give an exact meaning not only to *two* events, but to as many events as we care to choose, and independently of the positions of the scenes of the events with respect to the body of reference (here the railway embankment). We are thus led also to a definition of "time" in physics. For this purpose we suppose that clocks of identical construction are placed at the points A, B, and C of the railway line (co-ordinate system), and that they are set in such a manner that the positions of their pointers are simultaneously (in the above sense) the same. Under these conditions we understand by the "time" of an event the reading (position of the hands) of that one of these clocks which is in the immediate vicinity (in space) of the event. In this manner a time-value is associated with every event which is essentially capable of observation.

This stipulation contains a further physical hypothesis, the validity of which will hardly be doubted without empirical evidence to the contrary. It has been assumed that all these clocks go *at the same rate* if they are of identical construction. Stated more exactly : When two clocks arranged at rest in different places of a reference-body are set in such a manner that a *particular* position of the pointers of the one clock is *simultaneous* (in the above sense) with the *same* position of the pointers of the other clock, then identical " settings " are always simultaneous (in the sense of the above definition).

Up to now our considerations have been referred to a particular body of reference, which we have styled a " railway embankment." We suppose a very long train travelling along the rails with the constant velocity v and in the direction indicated in Diagram. People travelling in this train will with advantage use the train as a rigid reference-body (co-ordinate



system) ; they regard all events in reference to the train. Then every event which takes place along the line also takes place at a particular point of the train. Also the definition of simultaneity can be given relative to the train in exactly the same way as with respect to the embankment. As a natural consequence, however, the following question arises :

Are two events (*e.g.* the two strokes of lightning A and B) which are simultaneous *with reference to the railway embankment* also simultaneous *relatively to the train*? We shall show directly that the answer must be in the negative.

When we say that the lightning strokes A and B are simultaneous with respect to the embankment, we mean : the rays of light emitted at the places A and B, where the lightning occurs, meet each other at the mid-point M of the length $A \longrightarrow B$ of the embankment. But the events A and B also correspond to positions A and B on the train. Let M' be the mid-point of the distance $A \longrightarrow B$ on the travelling train. Just when the flashes* of lightning occur, this point M' naturally coincides with the point M, but it moves towards the right in the diagram with the velocity v of the train. If an observer sitting in the position M' in the train did not possess this velocity, then he would remain permanently at M, and the light rays emitted by the flashes of lightning A and B would reach him simultaneously, *i.e.* they would meet just where he is situated. Now in reality (considered with reference to the railway embankment) he is hastening towards the beam of light coming from B, whilst he is riding on ahead of the beam of light coming from A. Hence the observer will see the beam of light emitted from B earlier than he will see that emitted from A. Observers who take the railway train as their reference-body must therefore come to the conclusion that the lightning flash B took place earlier than the lightning flash A. We thus arrive at the important result :

Events which are simultaneous with reference to the embankment are not simultaneous with respect to the train, and *vice versa* (relativity of simultaneity). Every reference-body (co-ordinate system) has its own particular time ; unless we are told the reference-body to which the statement of time refers, there is no meaning in a statement of the time of an event.

Now before the advent of the theory of relativity it had always tacitly been assumed in physics that the statement of time had an absolute significance, *i.e.*

* As judged from the embankment.

that it is independent of the state of motion of the body of reference. But we have just seen that this assumption is incompatible with the most natural definition of simultaneity ; if we discard this assumption, then the conflict between the law of the propagation of light *in vacuo* and the principle of relativity (already developed) disappears.

We were led to that conflict by previous considerations which are now no longer tenable. We concluded that the man in the carriage, who traverses the distance *w per second* relative to the carriage, traverses the same distance also with respect to the embankment *in each second* of time. But, according to the foregoing considerations, the time required by a particular occurrence with respect to the carriage must not be considered equal to the duration of the same occurrence as judged from the embankment (as reference-body). Hence it cannot be contended that the man in walking travels the distance w relative to the railway line in a time which is equal to one second as judged from the embankment.

Moreover, our previous considerations are based on yet a second assumption, which, in the light of a strict consideration, appears to be arbitrary, although it was always tacitly made even before the introduction of the theory of relativity.

ALBERT EINSTEIN

SCIENCE AND ART

CLOUD FORMS AND PAINTING

It is a strange thing how little in general people know about the sky. It is the part of creation in which nature has done more for the sake of pleasing man, more for the sole and evident purpose of talking to him and teaching him, than in any other of her works, and it is just the part in which we least attend to her. There are not many of her other works in which some more material or essential purpose than the mere pleasing of man is not answered by every part of their organisation ; but every essential purpose of the sky might, so far as we know, be answered, if once in three days, or thereabouts, a great ugly black rain-cloud were brought up over the blue, and everything well watered, and so all left blue again till next time, with perhaps a film of morning and evening mist for dew. And instead of this, there is not a moment of any day of our lives, when nature is not producing scene after scene, picture after picture, glory after glory, and working still upon such exquisite and constant principles of the most perfect beauty, that it is quite certain that it is all done for us, and intended for our perpetual pleasure. And every man, wherever placed, however far from other sources of interest or of beauty, has this doing for him constantly. The noblest scenes of the earth can be seen and known but by few ; it is not intended that man should live always in the midst of them, he injures them by his presence, he ceases to feel them if he be always with them ; but the sky is for all ; bright as it is, it is

not "too bright or good for human nature's daily food"; it is fitted in all its functions for the perpetual comfort and exalting of the heart, for the soothing it and purifying it from its dross and dust. Sometimes gentle, sometimes capricious, sometimes awful, never the same for two moments together; almost human in its passions, almost spiritual in its tenderness, almost divine in its infinity, its appeal to what is immortal in us is as distinct as its ministry of chastisement or of blessing to what is mortal is essential. And yet we never attend to it, we never make it a subject of thought, but as it has to do with our animal sensations; we look upon all by which it speaks to us more clearly than to brutes, upon all which bears witness to the intention of the Supreme, that we are to receive more from the covering vault than the light and the dew which we share with the weed and the worm, only as a succession of meaningless and monotonous accident, too common and too vain to be worthy of a moment of watchfulness or a glance of admiration. If in our moments of utter idleness and insipidity, we turn to the sky as a last resource, which of its phenomena do we speak of? One says it has been wet, and another it has been windy, and another it has been warm. Who, among the whole chattering crowd, can tell me of the forms and the precipices of the chain of tall white mountains that girded the horizon at noon yesterday? Who saw the narrow sunbeam that came out of the south, and smote upon their summits until they melted and mouldered away in a dust of blue rain? Who saw the dance of the dead clouds when the sunlight left them last night, and the west wind blew them before it like withered leaves? All has passed, unregretted as unseen; or if the apathy be ever shaken off, even for an instant, it is only by what is gross, or what is extraordinary; and yet it is not in the broad and fierce manifestations of the elemental

energies, not in the clash of the hail, nor the drift of the whirlwind, that the highest characters of the sublime are developed. God is not in the earthquake, nor in the fire, but in the still small voice. They are but the blunt and the low faculties of our nature, which can only be addressed through lamp-black and lightning. It is in quiet and subdued passages of unobtrusive majesty, the deep, and the calm, and the perpetual,—that which must be sought ere it is seen, and loved ere it is understood,—things which the angels work out for us daily, and yet vary eternally, which are never wanting, and never repeated, which are to be found always, yet each one found but once; it is through these that the lesson of devotion is chiefly taught and the blessing of beauty given. These are what the artist of highest aim must study; it is these, by the combination of which his ideal is to be created; these, of which so little notice is ordinarily taken by common observers, that I fully believe, little as people in general are concerned with art, more of their ideas of sky are derived from pictures than from reality, and that if we could examine the conception formed in the minds of most educated persons when we talk of clouds, it would frequently be found composed of fragments of blue and white reminiscences of the old masters.

Let us begin then with the simple open blue of the sky. This is of course the colour of the pure atmospheric air, not the aqueous vapour, but the pure azote and oxygen, and it is the total colour of the whole mass of that air between us and the void of space. It is modified by the varying quantity of aqueous vapour suspended in it, whose colour, in its most imperfect, and therefore most visible, state of solution, is pure white (as in steam), which receives, like any other white, the warm hues of the rays of the sun, and, according to its quantity and imperfect solution, makes

the sky paler, and at the same time more or less grey, by mixing warm tones with its blue. This grey aqueous vapour, when very decided, becomes mist, and when local, cloud. Hence the sky is to be considered as a transparent blue liquid, in which, at various elevations, clouds are suspended, those clouds being themselves only particular visible spaces of a substance with which the whole mass of this liquid is more or less impregnated. Now, we all know this perfectly well, and yet we so far forget it in practice that we little notice the constant connection kept up by nature between her blue and her clouds, and we are not offended by the constant habit of the old masters, of considering the blue sky as totally distinct in its nature, and far separated from the vapours which float in it. With them, cloud is cloud, and blue is blue, and no kind of connection between them is ever hinted at. The sky is thought of as a clear, high material dome, the clouds as separate bodies suspended beneath it, and in consequence, however delicate and exquisitely removed in tone their skies may be, you always look *at* them, not *through* them. Now, if there be one characteristic of the sky more valuable or necessary to be rendered than another, it is that which Wordsworth has given in the second book of *The Excursion* :

The chasm of sky above my head
Is Heaven's profoundest azure. No domain
For fickle, short-lived clouds to occupy,
Or to pass through ;—but rather an *abyss*
In which the everlasting stars abide,
And whose soft gloom, and boundless depth, might tempt
The curious eye to look for them by day.

And, in his *American Notes*, I remember Dickens notices the same truth, describing himself as lying drowsily on the barge deck, looking not at, but *through* the sky.

And if you look intensely at the pure blue of a serene sky, you will see that there is a variety and fulness in its very repose. It is not flat dead colour, but a deep, quivering, transparent body of penetrable air, in which you trace or imagine short, falling spots of deceiving light, and dim shades, faint, veiled vestiges of dark vapour; and it is this trembling transparency which our great modern master has especially aimed at and given. His blue is never laid on in smooth coats, but in breaking, mingling, melting hues, a quarter of an inch of which, cut off from all the rest of the picture, is still *spacious*, still infinite and immeasurable in depth. It is a painting of the air, something into which you can see through the parts which are near you into those which are far off; something which has no surface, and through which we can plunge far and farther, and without stay or end, into the profundity of space;—whereas, with all the old landscape painters, except Claude, you may indeed go a long way before you come to the sky, but you will strike hard against it at last.

But there is a series of phenomena connected with the open blue of the sky which we must take especial notice of, as it is of constant occurrence in the works of Turner and Claude, the effects, namely, of visible sunbeams. It will be necessary for us thoroughly to understand the circumstances under which such effects take place.

Aqueous vapour or mist, suspended in the atmosphere, becomes visible exactly as dust does in the air of a room. In the shadows you not only cannot see the dust itself, because unillumined, but you can see other objects through the dust without obscurity, the air being thus actually rendered more transparent by a deprivation of light. Where a sunbeam enters, every particle of dust becomes visible, and a palpable interruption to the sight, so that a transverse sunbeam

is a real obstacle to the vision ; you cannot see things clearly through it.

In the same way, wherever vapour is illuminated by transverse rays there it becomes visible as a whiteness more or less affecting the purity of the blue, and destroying it exactly in proportion to the degree of illumination. But where vapour is in shade, it has very little effect on the sky, perhaps making it a little deeper and greyer than it otherwise would be, but not itself, unless very dense, distinguishable or felt as mist.

The appearance of mist or whiteness in the blue of the sky is thus a circumstance which more or less accompanies sunshine, and which, supposing the quantity of vapour constant, is greatest in the brightest sunlight. When there are no clouds in the sky, the whiteness, as it affects the whole sky equally, is not particularly noticeable. But when there are clouds between us and the sun, the sun being low, those clouds cast shadows along and through the mass of suspended vapour. Within the space of these shadows, the vapour, as above stated, becomes transparent and invisible, and the sky appears of a pure blue. But where the sunbeams strike, the vapour becomes visible in the form of the beams, occasioning those radiating shafts of light which are one of the most valuable and constant accompaniments of a low sun. The denser the mist, the more distinct and sharp-edged will these rays be ; when the air is very clear, they are mere vague, flushing, gradated passages of light ; when it is very thick, they are keen-edged and decisive in a high degree.

We see then, first, that a quantity of mist dispersed through the whole space of the sky is necessary to this phenomenon ; and secondly, that what we usually think of as beams of greater brightness than the rest of the sky are in reality only a part of that sky in its

natural state of illumination, cut off and rendered brilliant by the shadows from the clouds,—that these shadows are in reality the source of the appearance of beams,—that, therefore, no part of the sky can present such an appearance except when there are broken clouds between it and the sun ; and lastly, that the shadows cast from such clouds are not necessarily grey or dark, but very nearly of the natural pure blue of a sky destitute of vapour.

Now, as it has been proved that the appearance of beams can only take place in a part of the sky which has clouds between it and the sun, it is evident that no appearance of beams can ever begin from the orb itself, except when there is a cloud or solid body of some kind between us and it ; but that such appearances will almost invariably begin on the dark side of some of the clouds around it, the orb itself remaining the centre of a broad blaze of united light. Wordsworth has given us in two lines, the only circumstances under which rays can ever appear to have origin in the orb itself :

But rays of light,
Now *suddenly* diverging from the orb,
Retired behind the mountain tops, or veiled
By the dense air, shot upwards.

Excursion, Book IX

Our next subject of investigation must be the specific character of clouds, a species of truth which is especially neglected by artists ; first, because as it is within the limits of possibility that a cloud may assume almost any form, it is difficult to point out, and not always easy to feel, wherein error consists ; and secondly, because it is totally impossible to study the forms of clouds from nature with care and accuracy, as a change in the subject takes place between every touch of the following pencil, and parts of an out-

line sketched at different instants cannot harmonise, nature never having intended them to come together. Still if artists were more in the habit of sketching clouds rapidly, and as accurately as possible in the outline, from nature, instead of daubing down what they call "effects" with the brush, they would soon find there is more beauty about their forms than can be arrived at by any random felicity of invention, however brilliant, and more essential character than can be violated without incurring the charge of falsehood,—falsehood as direct and definite, though not as traceable, as error in the less varied features of organic form.

The first and most important character of clouds is dependent on the different altitudes at which they are formed. The atmosphere may be conveniently considered as divided into three spaces, each inhabited by clouds of specific character altogether different, though, in reality, there is no distinct limit fixed between them by nature, clouds being formed at *every* altitude, and partaking, according to their altitude, more or less of the characters of the upper or lower regions. The scenery of the sky is thus formed of an infinitely graduated series of systematic forms of cloud, each of which has its own region in which alone it is formed, and each of which has specific characters which can only be properly determined by comparing them as they are found clearly distinguished by intervals of considerable space. I shall therefore consider the sky as divided into three regions—the upper region, or region of the cirrus; the central region, or region of the stratus; the lower region, or the region of the rain-cloud.

The clouds which I wish to consider as included in the upper region never touch even the highest mountains of Europe, and may therefore be looked upon as never formed below an elevation of at least 15,000

ft.; they are the motionless multitudinous lines of delicate vapour with which the blue of the open sky is commonly streaked or speckled after several days of fine weather. I must be pardoned for giving a detailed description of their specific characters as they are of constant occurrence in the works of modern artists, and I shall have occasion to speak frequently of them in future parts of the work. Their chief characters are—first, Symmetry: They are nearly always arranged in some definite and evident order, commonly in long ranks reaching sometimes from the zenith to the horizon, each rank composed of an infinite number of transverse bars of about the same length, each bar thickest in the middle, and terminating in a traceless vaporous point at each side; the ranks are in the direction of the wind, and the bars of course at right angles to it; these latter are commonly slightly bent in the middle. Frequently two systems of this kind, indicative of two currents of wind, at different altitudes intersect one another, forming a network. Another frequent arrangement is in groups of excessively fine, silky, parallel fibres, commonly radiating, or having a tendency to radiate, from one of their extremities, and terminating in a plumy sweep at the other:—these are vulgarly known as "mares' tails." The plumy and expanded extremity of these is often bent upwards, sometimes back and up again, giving an appearance of great flexibility and unity at the same time, as if the clouds were tough, and would hold together however bent. The narrow extremity is invariably turned to the wind, and the fibres are parallel with its direction. The upper clouds always fall into some modification of one or other of these arrangements. They thus differ from all other clouds, in having a plan and system; whereas other clouds, though there are certain laws which they cannot break, have yet perfect freedom from anything like a relative

and general system of government. The upper clouds are to the lower what soldiers on parade are to a mixed multitude ; no men walk on their heads or their hands, and so there are certain laws which no clouds violate ; but there is nothing except in the upper clouds resembling symmetrical discipline.

Secondly, Sharpness of Edge : The edges of the bars of the upper clouds which are turned to the wind are often the sharpest which the sky shows ; no outline whatever of any other kind of cloud, however marked and energetic, ever approaches the delicate decision of these edges. The outline of a black thunder-cloud is striking, from the great energy of the colour or shade of the general mass ; but as a line it is soft and indistinct, compared with the edge of the cirrus, in a clear sky with a brisk breeze. On the other hand, the edge of the bar turned away from the wind is always soft, often imperceptible, melting into the blue interstice between it and its next neighbour. Commonly the sharper one edge is, the softer is the other, and the clouds look flat, and as if they slipped over each other like the scales of a fish. When both edges are soft, as is always the case when the sky is clear and windless, the cloud looks solid, round, and fleecy.

Thirdly, Multitude : The delicacy of these vapours is sometimes carried into such an infinity of division that no other sensation of number that the earth or heaven can give is so impressive. Number is always most felt when it is symmetrical (*vide* Burke on "Sublime," part ii, sect. 8), and, therefore, no sea-waves nor fresh leaves make their number so evident or so impressive as these vapours. Nor is nature content with an infinity of bars or lines alone—each bar is in its turn severed into a number of small undulatory masses, more or less connected according to the violence of the wind. When this division is

merely effected by undulation, the cloud exactly resembles sea-sand ribbed by the tide ; but when the division amounts to real separation we have the mottled or mackerel skies. Commonly, the greater the division of its bars, the broader and more shapeless is the rank or field, so that in the mottled sky it is lost altogether, and we have large irregular fields of equal size, masses like flocks of sheep ; such clouds are 3000 or 4000 ft. below the legitimate cirrus. I have seen them cast a shadow on the Mont Blanc at sunset, so that they must descend nearly to within 15,000 ft. of the earth.

Fourthly, Purity of Colour : The nearest of these clouds—those over the observer's head, being at least three miles above him, and nearly all entering the ordinary sphere of vision, farther from him still,—their dark sides are much greyer and cooler than those of other clouds, owing to their distance. They are composed of the purest aqueous vapour, free from all foulness of earthy gases, and of this in the lightest and most aethereal state in which it can be, to be visible. Farther, they receive the light of the sun in a state of far greater intensity than lower objects, the beams being transmitted to them through atmospheric air far less dense, and wholly unaffected by mist, smoke, or any other impurity. Hence their colours are more pure and vivid, and their white less sullied than those of any other clouds.

Lastly, Variety : Variety is never so conspicuous as when it is united with symmetry. The perpetual change of form in other clouds is monotonous in its very dissimilarity, nor is difference striking where no connexion is implied ; but if through a range of barred clouds, crossing half the heaven, all governed by the same forces and falling into one general form, there be yet a marked and evident dissimilarity between each member of the great mass—one more

finely drawn, the next more delicately moulded, the next more gracefully bent—each broken into differently modelled and variously numbered groups, the variety is doubly striking, because contrasted with the perfect symmetry of which it forms a part. Hence, the importance of the truth, that nature never lets one of the members of even her most disciplined groups of cloud be like another ; but though each is adapted for the same function, and in its great features resembles all the others, not one, out of the millions with which the sky is chequered, is without a separate beauty and character, appearing to have had distinct thought occupied in its conception, and distinct forces in its production ; and in addition to this perpetual invention, visible in each member of each system, we find systems of separate cloud intersecting one another, the sweeping lines mingled and interwoven with the rigid bars, these in their turn melting into banks of sand-like ripple and flakes of drifted and irregular foam ; under all, perhaps the massy outline of some lower cloud moves heavily across the motionless buoyancy of the upper lines, and indicates at once their elevation and their repose.

We have next to investigate the character of the Central Cloud Region, which I consider as including all clouds which are the usual characteristic of ordinary serene weather, and which touch and envelop the mountains of Switzerland, but never affect those of our own island ; they may therefore be considered as occupying a space of air 10,000 ft. in height, extending from 5000 to 15,000 ft. above the sea.

These clouds, according to their elevation, appear with great variety of form, often partaking of the streaked or mottled character of the higher region, and as often, when the precursors of storm, manifesting

forms closely connected with the lowest rain-clouds; but the species especially characteristic of the central region is a white, ragged, irregular, and scattered vapour, which has little form and less colour, and of which a good example may be seen in the largest landscape of Cuyp, in the Dulwich Gallery. When this vapour collects into masses, it is partially rounded, clumsy, and ponderous, as if it would tumble out of the sky, shaded with a dull grey, and totally devoid of any appearance of energy or motion. Even in nature, these clouds are comparatively uninteresting, scarcely worth raising our heads to look at; and on canvas valuable only as a means of introducing light and breaking the monotony of blue; yet they are, perhaps, beyond all others the favourite clouds of the Dutch masters. Whether they had any motive for the adoption of such materials, beyond the extreme facility with which acres of canvas might thus be covered without any troublesome exertion of thought; or any temptation to such selections beyond the impossibility of error where nature shows no form, and the impossibility of deficiency where she shows no beauty, it is not here the place to determine. Such skies are happily beyond the reach of criticism, for he who tells you nothing cannot tell you a falsehood. A little flake-white, glazed with a light brush over the carefully toned blue, permitted to fall into whatever forms chance might determine, with the single precaution that their edges should be tolerably irregular, supplied, in hundreds of instances, a sky quite good enough for all ordinary purposes—quite good enough for cattle to graze or boors to play at nine-pins under—and equally devoid of all that could gratify, inform, or offend.

But although this kind of cloud is, as I have said, typical of the central region, it is not one which nature is fond of. She scarcely ever lets an hour pass without

some manifestation of finer forms, sometimes approaching the upper cirri, sometimes the lower cumulus. And then in the lower outlines we have the nearest approximation which nature ever presents to the clouds of Claude, Salvator, and Poussin, to the characters of which I must request especial attention, as it is here only that we shall have a fair opportunity of comparing their skies with those of the modern school. I shall, as before, glance rapidly at the great laws of specific form, and so put it in the power of the reader to judge for himself of the truth of representation.

Clouds, it is to be remembered, are not so much local vapour, as vapour rendered locally visible by a fall of temperature. Thus a cloud, whose parts are in constant motion, will hover on a snowy mountain, pursuing constantly the same track upon its flanks, and yet remaining of the same size, the same form, and in the same place, for half a day together. No matter how violent or how capricious the wind may be, the instant it approaches the spot where the chilly influence of the snow extends, the moisture it carries becomes visible, and then and there the cloud forms on the instant, apparently maintaining its form against the wind, though the careful and keen eye can see all its parts in the most rapid motion across the mountain. The outlines of such a cloud are of course not determined by the irregular impulses of the wind, but by the fixed lines of radiant heat which regulate the temperature of the atmosphere of the mountain. It is terminated, therefore, not by changing curves, but by steady right lines of more or less decision, often exactly correspondent with the outline of the mountain on which it is formed, and falling therefore into grotesque peaks and precipices. I have seen the marked and angular outline of the Grandes Jorasses, at Chamounix, mimicked in its every jag by a line of clouds above it. Another resultant phenomenon is

the formation of cloud in the calm air to leeward of a steep summit ; cloud whose edges are in rapid motion, where they are affected by the current of the wind above, and stream from the peak like the smoke of a volcano, yet always vanish at a certain distance from it as steam issuing from a chimney. When wet weather of some duration is approaching, a small white spot of cloud will sometimes appear low on the hill flanks ; it will not move, but will increase gradually for some little time, then diminish, still without moving ; disappear altogether, reappear ten minutes afterwards, exactly in the same spot ; increase to a greater extent than before, again disappear, again return, and at last permanently ; other similar spots of cloud forming simultaneously, with various fluctuations, each in its own spot, and at the same level on the hill-side, until all expand, join together, and form an unbroken veil of threatening grey, which darkens gradually into storm. What in such cases takes place palpably and remarkably is more or less a law of formation in all clouds whatsoever ; they being bounded rather by lines expressive of changes of temperature in the atmosphere, than by the impulses of the currents of wind in which those changes take place. Even when in rapid and visible motion across the sky, the variations which take place in their outlines are not so much alterations of position and arrangement of parts, as they are the alternate formation and disappearance of parts. There is, therefore, usually a parallelism and consistency in their great outlines which give system to the smaller curves of which they are composed ; and if these great lines be taken, rejecting the minutiae of variation, the resultant form will almost always be angular, and full of character and decision. In the flock-like fields of equal masses, each individual mass has the effect, not of an ellipse or circle, but of a rhomboid ; the sky is

crossed and chequered, not honeycombed ; in the lower cumuli, even though the most rounded of all clouds, the groups are not like balloons or bubbles, but like towers or mountains. And the result of this arrangement in masses more or less angular, varied with, and chiefly constructed of, curves of the utmost freedom and beauty, is that appearance of exhaustless and fantastic energy which gives every cloud a marked character of its own, suggesting resemblances to the specific outlines of organic objects. I do not say that such accidental resemblances are a character to be imitated ; but merely that they bear witness to the originality and vigour of separate conception in cloud forms, which give to the scenery of the sky a force and variety no less delightful than that of the changes of mountain outline in a hill district of great elevation ; and that there is added to this a spirit-like feeling, a capricious, mocking imagery of passion and life, totally different from any effects of inanimate form that the earth can show.

The minor contours, out of which the larger outlines are composed, are indeed beautifully curvilinear; but they are never monotonous in their curves. First comes a concave line, then a convex one, then an angular jag, breaking off into spray, then a downright straight line, then a curve again, then a deep gap, and a place where all is lost and melted away, and so on ; displaying in every inch of the form renewed and ceaseless invention, setting off grace with rigidity, and relieving flexibility with force, in a manner scarcely less admirable, and far more changeful than even in the muscular forms of the human frame. Nay, such is the exquisite composition of all this, that you may take any single fragment of any cloud in the sky, and you will find it put together as if there had been a year's thought over the plan of it, arranged with the most studied inequality—with the most

delicate symmetry—with the most elaborate contrast, a picture in itself. You may try every other piece of cloud in the heaven, and you will find them every one as perfect, and yet not one in the least like another.

The clouds which I wish to consider as characteristic of the lower, or rainy region, differ not so much in their real nature from those of the central and uppermost regions, as in appearance, owing to their greater nearness. For the central clouds, and perhaps even the high cirri, deposit moisture, if not distinctly rain, as is sufficiently proved by the existence of snow on the highest peaks of the Himaleh ; and when, on any such mountains, we are brought into close contact with the central clouds * we find them little differing from the ordinary rain-cloud of the plains, except by being slightly less dense and dark. But the apparent differences, dependent on proximity, are most marked and important.

In the first place, the clouds of the central region have, as has been before observed, pure and aerial greys for their dark sides, owing to their necessary distance from the observer ; and as this distance permits a multitude of local phenomena capable of influencing colour, such as accidental sunbeams, refractions, transparencies, or local mists and showers, to be collected into a space apparently small, the colours of these clouds are always changeful and palpitating ; and whatever degree of grey or of gloom may be mixed with them is invariably pure and aerial. But the nearness of the rain-cloud rendering it impossible for a number of phenomena to be at

* I am unable to say to what height the real rain-cloud may extend ; perhaps there are no mountains which rise altogether above storm. I have never been in a violent storm at a greater height than between 8000 and 9000 ft. above the level of the sea. There the rain-cloud is exceedingly light, compared to the ponderous darkness of the lower air.

once visible, makes its hue of grey monotonous, and (by losing the blue of distance) warm and brown compared to that of the upper clouds. This is especially remarkable on any part of it which may happen to be illumined, which is of a brown, bricky, ochreous tone, never bright, always coming in dark outline on the lights of the central clouds. But it is seldom that this takes place, and when it does, never over large spaces, little being usually seen of the rain-cloud but its under and dark side. This, when the cloud above is dense, becomes of an inky and cold grey, and sulphureous and lurid if there be thunder in the air.

With these striking differences in colour, it presents no fewer nor less important in form, chiefly from losing almost all definiteness of character and outline. It is sometimes nothing more than a thin mist, whose outline cannot be traced, rendering the landscape locally indistinct or dark ; if its outline be visible, it is ragged and torn ; rather a spray of cloud, taken off its edge and sifted by the wind, than an edge of the cloud itself. In fact, it rather partakes of the nature, and assumes the appearance, of real water in the state of spray, than of elastic vapour. This appearance is enhanced by the usual presence of formed rain, carried along with it in a columnar form, ordinarily, of course, reaching the ground like a veil, but very often suspended with the cloud, and hanging from it like a jagged fringe, or over it in light, rain being always lighter than the cloud it falls from. These columns, or fringes, of rain are often waved and bent by the wind, or twisted, sometimes even swept upwards from the cloud. The velocity of these vapours, though not necessarily in reality greater than that of the central clouds, appears greater, owing to their proximity, and, of course, also to the usual presence of a more violent wind. They are also apparently

much more in the power of the wind, having less elastic force in themselves ; but they are precisely subject to the same great laws of form which regulate the upper clouds. They are not solid bodies borne about with the wind, but they carry the wind with them, and cause it. Every one knows, who has ever been out in a storm, that the time when it rains heaviest is precisely the time when he cannot hold up his umbrella ; that the wind is carried with the cloud, and lulls when it has passed. Every one who has ever seen rain in a hill country knows that a rain-cloud, like any other, may have all its parts in rapid motion, and yet, as a whole, remain in one spot. I remember once when, in crossing the Tête Noire, I had turned up the valley towards Trient, I noticed a rain-cloud forming on the Glacier de Trient. With a west wind, it proceeded towards the Col de Balme, being followed by a prolonged wreath of vapour, always forming exactly at the same spot over the glacier. This long, serpent-like line of cloud went on at a great rate till it reached the valley leading down from the Col de Balme, under the slate rocks of the Croix de Fer. There it turned sharp round, and came down this valley, at right angles to its former progress, and finally directly contrary to it, till it came down within 500 ft. of the village, where it disappeared ; the line behind always advancing, and always disappearing, at the same spot. This continued for half an hour, the long line describing the curve of a horse-shoe ; always coming into existence, and always vanishing at exactly the same places ; traversing the space between with enormous swiftness. This cloud, ten miles off, would have looked like a perfectly motionless wreath, in the form of a horse-shoe hanging over the hills.

To the region of the rain-cloud belong also all those phenomena of drifted smoke, heat-haze, local mists in

the morning or evening ; in valleys, or over water, mirage, white steaming vapour rising in evaporation from moist and open surfaces, and everything which visibly affects the condition of the atmosphere without actually assuming the form of cloud. These phenomena are as perpetual in all countries as they are beautiful, and afford by far the most effective and valuable means which the painter possesses, for modification of the forms of fixed objects. The upper clouds are distinct and comparatively opaque, they do not modify, but conceal ; but through the rain-cloud, and its accessory phenomena, all that is beautiful may be made manifest, and all that is hurtful concealed ; what is paltry may be made to look vast, and what is ponderous, aerial ; mystery may be obtained without obscurity, and decoration without disguise. And, accordingly, nature herself uses it constantly, as one of her chief means of most perfect effect ; not in one country, nor another, but everywhere—everywhere, at least, where there is anything worth calling landscape. I cannot answer for the desert of the Sahara, but I know that there can be no greater mistake than supposing that delicate and variable effects of mist and rain-cloud are peculiar to northern climates. I have never seen in any place or country effects of mist more perfect than in the Campagna of Rome and among the hills of Sorrento. It is therefore matter of no little marvel to me, and I conceive that it can scarcely be otherwise to any reflecting person, that throughout the whole range of ancient landscape art there occurs no instance of the painting of a real rain-cloud, still less of any of the more delicate phenomena characteristic of the region. " Storms " indeed, as the innocent public persist in calling such abuses of nature and abortions of art as the two windy Gaspars in our National Gallery, are common enough ; massive concretions of ink and

indigo, wrung and twisted very hard, apparently in a vain effort to get some moisture out of them ; bearing up courageously and successfully against a wind, whose effects on the trees in the foreground can be accounted for only on the supposition that they are all of the india-rubber species. Enough of this in all conscience we have, and to spare ; but for the legitimate rain-cloud, with its ragged and spray-like edge, its veilly transparency, and its columnar burden of blessing, neither it, nor anything like it, or approaching it, occurs in any painting of the old masters that I have ever seen ; and I have seen enough to warrant my affirming that if it occur anywhere it must be through accident rather than intention. Nor is there stronger evidence of any perception, on the part of these much respected artists, that there were such things in the world as mists or vapours. If a cloud under their direction ever touches a mountain, it does it effectually and as if it meant to do it. There is no mystifying the matter ; here is a cloud, and there is a hill ; if it is to come on at all, it comes on to some purpose, and there is no hope of its ever going off again. We have, therefore, little to say of the efforts of the old masters, in any scenes which might naturally have been connected with the clouds of the lowest region, except that the faults of form specified in considering the central clouds, are, by way of being energetic or sublime, more glaringly and audaciously committed in their " storms " ; and that what is a wrong form among clouds possessing form, is there given with increased generosity of fiction to clouds which have no form at all.

JOHN RUSKIN

FICTION

THE TIME MACHINE

Part I

The Time Traveller (for so it will be convenient to speak of him) was expounding a recondite matter to us. His grey eyes shone and twinkled, and his usually pale face was flushed and animated. The fire burnt brightly, and the soft radiance of the incandescent lights in the lilies of silver caught the bubbles that flashed and passed in our glasses. Our chairs, being his patents, embraced and caressed us rather than submitted to be sat upon, and there was that luxurious after-dinner atmosphere, when thought runs gracefully free of the trammels of precision. And he put it to us in this way—marking the points with a lean forefinger—as we sat and lazily admired his earnestness over this new paradox (as we thought it) and his fecundity.

"You must follow me carefully. I shall have to controvert one or two ideas that are almost universally accepted. The geometry, for instance, they taught you at school is founded on a misconception."

"Is not that rather a large thing to expect us to begin upon?" said Filby, an argumentative person with red hair.

"I do not mean to ask you to accept anything without reasonable ground for it. You will soon admit as much as I need from you. You know of course that a mathematical line, a line of thickness *nil*, has no real existence. They taught you that? Neither has a

mathematical plane. These things are mere abstractions."

"That is all right," said the Psychologist.

"Nor, having only length, breadth, and thickness, can a cube have a real existence."

"There I object," said Filby. "Of course a solid body may exist. All real things——"

"So most people think. But wait a moment. Can an *instantaneous* cube exist?"

"Don't follow you," said Filby.

"Can a cube that does not last for any time at all have a real existence?"

Filby became pensive. "Clearly," the Time Traveller proceeded, "any real body must have extension in *four* directions: it must have Length, Breadth, Thickness, and—Duration. But through a natural infirmity of the flesh, which I will explain to you in a moment, we incline to overlook this fact. There are really four dimensions, three which we call the three planes of Space, and a fourth, Time. There is, however, a tendency to draw an unreal distinction between the former three dimensions and the latter, because it happens that our consciousness moves intermittently in one direction along the latter from the beginning to the end of our lives."

"That," said a very young man, making spasmodic efforts to relight his cigar over the lamp; "that . . . very clear indeed."

"Now, it is very remarkable that this is so extensively overlooked," continued the Time Traveller, with a slight accession of cheerfulness. "Really this is what is meant by the Fourth Dimension, though some people who talk about the Fourth Dimension do not know they mean it. It is only another way of looking at Time. *There is no difference between Time and any of the three dimensions of Space except that our consciousness moves along it.* But some foolish people have got

hold of the wrong side of that idea. You have all heard what they have to say about this Fourth Dimension ? "

" *I* have not," said the Provincial Mayor.

" It is simply this. That Space, as our mathematicians have it, is spoken of as having three dimensions, which one may call Length, Breadth, and Thickness, and is always definable by reference to three planes, each at right angles to the others. But some philosophical people have been asking why *three* dimensions particularly—why not another direction at right angles to the other three ?—and have even tried to construct a Four-Dimensional geometry. Professor Simon Newcomb was expounding this to the New York Mathematical Society only a month or so ago. You know how on a flat surface, which has only two dimensions, we can represent a figure of a three-dimensional solid, and similarly they think that by models of three dimensions they could represent one of four—if they could master the perspective of the thing. See ? "

" I think so," murmured the Provincial Mayor ; and, knitting his brows, he lapsed into an introspective state, his lips moving as one who repeats mystic words. " Yes, I think I see it now," he said after some time, brightening in a quite transitory manner.

" Well, I do not mind telling you I have been at work upon this geometry of Four Dimensions for some time. Some of my results are curious. For instance, here is a portrait of a man at eight years old, another at fifteen, another at seventeen, another at twenty-three, and so on. All these are evidently sections, as it were, Three-Dimensional representations of his Four-Dimensioned being, which is a fixed and unalterable thing."

" Scientific people," proceeded the Time Traveller, after the pause required for the proper assimilation of

this, " know very well that Time is only a kind of Space. Here is a popular scientific diagram, a weather record. This line I trace with my finger shows the movement of the barometer. Yesterday it was so high, yesterday night it fell, then this morning it rose again, and so gently upward to here. Surely the mercury did not trace this line in any of the dimensions of Space generally recognised? But certainly it traced such a line, and that line, therefore, we must conclude was along the Time-Dimension."

" But," said the Medical Man, staring hard at a coal in the fire, " if Time is really only a fourth dimension of Space, why is it, and why has it always been, regarded as something different? And why cannot we move about in Time as we move about in the other dimensions of Space? "

The Time Traveller smiled. " Are you so sure we can move freely in Space? Right and left we can go, backward and forward freely enough, and men always have done so. I admit we move freely in two dimensions. But how about up and down? Gravitation limits us there."

" Not exactly," said the Medical Man. " There are balloons."

" But before the balloons, save for spasmodic jumping and the inequalities of the surface, man had no freedom of vertical movement."

" Still, they could move a little up and down," said the Medical Man.

" Easier, far easier down than up."

" And you cannot move at all in Time, you cannot get away from the present moment."

" My dear sir, that is just where you are wrong. That is just where the whole world has gone wrong. We are always getting away from the present moment. Our mental existences, which are immaterial and have no dimensions, are passing along the Time-Dimension

with a uniform velocity from the cradle to the grave. Just as we should travel *down* if we began our existence fifty miles above the earth's surface."

"But the great difficulty is this," interrupted the Psychologist. "You *can* move about in all directions of Space, but you cannot move about in Time."

"That is the germ of my great discovery. But you are wrong to say that we cannot move about in Time. For instance, if I am recalling an incident very vividly I go back to the instant of its occurrence: I become absent-minded, as you say. I jump back for a moment. Of course we have no means of staying back for any length of Time, any more than a savage or an animal has of staying six feet above the ground. But a civilised man is better off than the savage in this respect. He can go up against gravitation in a balloon, and why should he not hope that ultimately he may be able to stop or accelerate his drift along the Time-Dimension, or even turn about and travel the other way?"

"Oh, *this*," began Filby, "is all——"

"Why not?" said the Time Traveller.

"It's against reason," said Filby.

"What reason?" said the Time Traveller.

"You can show black is white by argument," said Filby, "but you will never convince me."

"Possibly not," said the Time Traveller. "But now you begin to see the object of my investigations into the geometry of Four Dimensions. Long ago I had a vague inkling of a machine——"

"To travel through Time!" exclaimed the Very Young Man.

"That shall travel indifferently in any direction of Space and Time, as the driver determines."

Filby contented himself with laughter.

"But I have experimental verification," said the Time Traveller.

"It would be remarkably convenient for the his-

torian," the Psychologist suggested. "One might travel back and verify the accepted account of the Battle of Hastings, for instance!"

"Don't you think you would attract attention?" said the Medical Man. "Our ancestors had no great tolerance for anachronisms."

"One might get one's Greek from the very lips of Homer and Plato," the Very Young Man thought.

"In which case they would certainly plough you for the Little-go. The German scholars have improved Greek so much."

"Then there is the future," said the Very Young Man. "Just think! One might invest all one's money, leave it to accumulate at interest, and hurry on ahead!"

"To discover a society," said I, "erected on a strictly communistic basis."

"Of all the wild, extravagant theories!" began the Psychologist.

"Yes, so it seemed to me, and so I never talked of it until——"

"Experimental verification!" cried I. "You are going to verify *that*?"

"The experiment!" cried Filby, who was getting brain-weary.

"Let's see your experiment anyhow," said the Psychologist, "though it's all humbug, you know."

The Time Traveller smiled round at us. Then, still smiling faintly, and with his hands deep in his trousers-pockets, he walked slowly out of the room, and we heard his slippers shuffling down the long passage to his laboratory.

The Psychologist looked at us. "I wonder what he's got?"

"Some sleight-of-hand trick or other," said the Medical Man, and Filby tried to tell us about a conjurer he had seen at Burslem, but before he had

finished his preface the Time Traveller came back, and Filby's anecdote collapsed.

The thing the Time Traveller held in his hand was a glittering metallic framework, scarcely larger than a small clock, and very delicately made. There was ivory in it, and some transparent crystalline substance. And now I must be explicit, for this that follows—unless his explanation is to be accepted—is an absolutely unaccountable thing. He took one of the small octagonal tables that were scattered about the room, and set it in front of the fire, with two legs on the hearthrug. On this table he placed the mechanism. Then he drew up a chair, and sat down. The only other object on the table was a small shaded lamp, the bright light of which fell full upon the model. There were also perhaps a dozen candles about, two in brass candlesticks upon the mantel and several in sconces, so that the room was brilliantly illuminated. I sat in a low arm-chair nearest the fire, and I drew this forward so as to be almost between the Time Traveller and the fireplace. Filby sat behind him, looking over his shoulder. The Medical Man and the Provincial Mayor watched him in profile from the right, the Psychologist from the left. The Very Young Man stood behind the Psychologist. We were all on the alert. It appears incredible to me that any kind of trick, however subtly conceived and however adroitly done, could have been played upon us under these conditions.

The Time Traveller looked at us, and then at the mechanism. " Well ? " said the Psychologist.

" This little affair," said the Time Traveller, resting his elbows upon the table and pressing his hands together above the apparatus, " is only a model. It is my plan for a machine to travel through time. You will notice that it looks singularly askew, and that

there is an odd twinkling appearance about this bar, as though it was in some way unreal." He pointed to the part with his finger. " Also, here is one little white lever, and here is another."

The Medical Man got up out of his chair and peered into the thing. " It's beautifully made," he said.

" It took two years to make," retorted the Time Traveller. Then, when we had all imitated the action of the Medical Man, he said : " Now I want you clearly to understand that this lever, being pressed over, sends the machine gliding into the future, and this other reverses the motion. This saddle represents the seat of a time traveller. Presently I am going to press the lever, and off the machine will go. It will vanish, pass into future time, and disappear. Have a good look at the thing. Look at the table too, and satisfy yourselves there is no trickery. I don't want to waste this model, and then be told I'm a quack."

There was a minute's pause perhaps. The Psychologist seemed about to speak to me, but changed his mind. Then the Time Traveller put forth his finger towards the lever. " No," he said suddenly. " Lend me your hand." And turning to the Psychologist, he took that individual's hand in his own and told him to put out his forefinger. So that it was the Psychologist himself who sent forth the model Time Machine on its interminable voyage. We all saw the lever turn. I am absolutely certain there was no trickery. There was a breath of wind, and the lamp flame jumped. One of the candles on the mantel was blown out, and the little machine suddenly swung round, became indistinct, was seen as a ghost for a second perhaps, as an eddy of faintly glittering brass and ivory ; and it was gone—vanished ! Save for the lamp the table was bare.

. . . . . .

" Would you like to see the Time Machine itself ? "

asked the Time Traveller. And therewith, taking the lamp in his hand, he led the way down the long, draughty corridor to his laboratory. I remember vividly the flickering light, his queer broad head in silhouette, the dance of the shadows, how we all followed him, puzzled but incredulous, and how there in the laboratory we beheld a larger edition of the little mechanism which we had seen vanish from before our eyes. Parts were of nickel, parts of ivory, parts had certainly been filed or sawn out of rock crystal. The thing was generally complete, but the twisted crystalline bars lay unfinished upon the bench beside some sheets of drawings, and I took one up for a better look at it. Quartz it seemed to me.

" Look here," said the Medical Man, " are you perfectly serious ? Or is this a trick—like that ghost you showed us last Christmas ? "

" Upon that machine," said the Time Traveller, holding the lamp aloft, " I intend to explore time. Is that plain ? I was never more serious in my life."

Part II

" I told some of you last Thursday of the principles of the Time Machine, and showed you the actual thing itself, incomplete in the workshop. There it is now, a little travel-worn, truly ; and one of the ivory bars is cracked, and a brass rail bent ; but the rest of it's sound enough. I expected to finish it on Friday ; but on Friday, when the putting together was nearly done, I found that one of the nickel bars was exactly one inch too short, and this I had to get remade ; so that the thing was not complete until this morning. It was at ten o'clock to-day that the first of all Time Machines began its career. I gave it a last tap, tried all the screws again, put one more drop of oil on the quartz rod, and sat myself in the saddle. I

suppose a suicide who holds a pistol to his skull feels much the same wonder at what will come next as I felt then. I took the starting lever in one hand and the stopping one in the other, pressed the first, and almost immediately the second. I seemed to reel ; I felt a nightmare sensation of falling ; and, looking round, I saw the laboratory exactly as before. Had anything happened ? For a moment I suspected that my intellect had tricked me. Then I noted the clock. A moment before, as it seemed, it had stood at a minute or so past ten ; now it was nearly half-past three !

" I drew a breath, set my teeth, gripped the starting lever with both hands, and went off with a thud. The laboratory got hazy and went dark. Mrs. Watchett came in, and walked, apparently without seeing me, towards the garden door. I suppose it took her a minute or so to traverse the place, but to me she seemed to shoot across the room like a rocket. I pressed the lever over to its extreme position. The night came like the turning out of a lamp, and in another moment came to-morrow. The laboratory grew faint and hazy, then fainter and even fainter. To-morrow night came black, then day again, night again, day again, faster and faster still. An eddying murmur filled my ears, and a strange, dumb confusedness descended on my mind.

" I am afraid I cannot convey the peculiar sensations of time travelling. They are excessively unpleasant. There is a feeling exactly like that one has upon a switchback—of a helpless headlong motion ! I felt the same horrible anticipation, too, of an imminent smash. As I put on pace, night followed day like the flapping of a black wing. The dim suggestion of the laboratory seemed presently to fall away from me, and I saw the sun hopping swiftly across the sky, leaping it every minute, and every minute marking

a day. I supposed the laboratory had been destroyed, and I had come into the open air. I had a dim impression of scaffolding, but I was already going too fast to be conscious of any moving things. The slowest snail that ever crawled dashed by too fast for me. The twinkling succession of darkness and light was excessively painful to the eye. Then, in the intermittent darknesses, I saw the moon spinning swiftly through her quarters from new to full, and had a faint glimpse of the circling stars. Presently, as I went on, still gaining velocity, the palpitation of night and day merged into one continuous greyness ; the sky took on a wonderful deepness of blue, a splendid luminous colour like that of early twilight ; the jerking sun became a streak of fire, a brilliant arch, in space, the moon a fainter fluctuating band ; and I could see nothing of the stars, save now and then a brighter circle flickering in the blue.

" The landscape was misty and vague. I was still on the hill-side upon which this house now stands, and the shoulder rose above me grey and dim. I saw trees growing and changing like puffs of vapour, now brown, now green : they grew, spread, shivered, and passed away. I saw huge buildings rise up faint and fair, and pass like dreams. The whole surface of the earth seemed changed—melting and flowing under my eyes. The little hands upon the dials that registered my speed raced round faster and faster. Presently I noted that the sun-belt swayed up and down, from solstice to solstice, in a minute or less, and that, consequently, my pace was over a year a minute ; and minute by minute the white snow flashed across the world, and vanished, and was followed by the bright, brief green of spring.

" The unpleasant sensations of the start were less poignant now. They merged at last into a kind of hysterical exhilaration. I remarked, indeed, a clumsy

swaying of the machine, for which I was unable to account. But my mind was too confused to attend to it, so with a kind of madness growing upon me, I flung myself into futurity. At first I scarce thought of stopping, scarce thought of anything but these new sensations. But presently a fresh series of impressions grew up in my mind—a certain curiosity and therewith a certain dread—until at last they took complete possession of me. What strange developments of humanity, what wonderful advances upon our rudimentary civilisation, I thought, might not appear when I came to look nearly into the dim elusive world that raced and fluctuated before my eyes ! I saw great and splendid architecture rising about me, more massive than any buildings of our own time, and yet, as it seemed, built of glimmer and mist. I saw a richer green flow up the hill-side, and remain there without any wintry intermission. Even through the veil of my confusion the earth seemed very fair. And so my mind came round to the business of stopping.

" The peculiar risk lay in the possibility of my finding some substance in the space which I, or the machine, occupied. So long as I travelled at a high velocity through time, this scarcely mattered : I was, so to speak, attenuated—was slipping like a vapour through the interstices of intervening substances ! But to come to a stop involved the jamming of myself, molecule by molecule, into whatever lay in my way : meant bringing my atoms into such intimate contact with those of the obstacle that a profound chemical reaction—possibly a far-reaching explosion—would result, and blow myself and my apparatus out of all possible dimensions—into the Unknown. This possibility had occurred to me again and again while I was making the machine ; but then I had cheerfully accepted it as an unavoidable risk—one of the risks a man has got to take ! Now the risk was inevitable, I

no longer saw it in the same cheerful light. The fact is that, insensibly, the absolute strangeness of everything, the sickly jarring and swaying of the machine, above all, the feeling of prolonged falling, had absolutely upset my nerve. I told myself that I could never stop, and with a gust of petulance I resolved to stop forthwith. Like an impatient fool, I lugged over the lever, and incontinently the thing went reeling over, and I was flung headlong through the air.

" There was the sound of a clap of thunder in my ears. I may have been stunned for a moment. A pitiless hail was hissing round me, and I was sitting on soft turf in front of the overset machine. Everything still seemed grey, but presently I remarked that the confusion in my ears was gone. I looked round me. I was on what seemed to be a little lawn in a garden, surrounded by rhododendron bushes, and I noticed that their mauve and purple blossoms were dropping in a shower under the beating of the hailstones. The rebounding, dancing hail hung in a little cloud over the machine, and drove along the ground like smoke. In a moment I was wet to the skin. ' Fine hospitality,' said I, ' to a man who has travelled innumerable years to see you.'

" Presently I thought what a fool I was to get wet. I stood up and looked round me. A colossal figure, carved apparently in some white stone, loomed indistinctly beyond the rhododendrons through the hazy downpour. But all else of the world was invisible.

" My sensations would be hard to describe. As the columns of hail grew thinner, I saw the white figure more distinctly. It was very large, for a silver birch tree touched its shoulder. It was of white marble, in shape something like a winged sphinx, but the wings, instead of being carried vertically at the sides, were spread so that it seemed to hover. The pedestal, it appeared to me, was of bronze, and was thick with

verdigris. It chanced that the face was towards me ; the sightless eyes seemed to watch me ; there was the faint shadow of a smile on the lips. It was greatly weather-worn, and that imparted an unpleasant suggestion of disease. I stood looking at it for a little space—half a minute, perhaps, or half an hour. It seemed to advance and to recede as the hail drove before it denser or thinner. At last I tore my eyes from it for a moment, and saw that the hail curtain had worn threadbare, and that the sky was lightening with the promise of the sun.

" I looked up again at the crouching white shape, and the full temerity of my voyage came suddenly upon me. What might appear when that hazy curtain was altogether withdrawn ? What might not have happened to men ? What if cruelty had grown into a common passion ? What if in this interval the race had lost its manliness, and had developed into something inhuman, unsympathetic, and overwhelmingly powerful ? I might seem some old-world savage animal, only the more dreadful and disgusting for our common likeness—a foul creature to be incontinently slain.

" Already I saw other vast shapes—huge buildings with intricate parapets and tall columns, with a wooded hill-side dimly creeping in upon me through the lessening storm. I was seized with a panic fear. I turned frantically to the Time Machine, and strove hard to readjust it. As I did so the shafts of the sun smote through the thunderstorm. The grey downpour was swept aside and vanished like the trailing garments of a ghost. Above me, in the intense blue of the summer sky, some faint brown shreds of cloud whirled into nothingness. The great buildings about me stood out clear and distinct, shining with the wet of the thunderstorm, and picked out in white by the unmelted hailstones piled along their courses. I felt

naked in a strange world. I felt as perhaps a bird may feel in the clear air, knowing the hawk wins above and will swoop. My fear grew to frenzy. I took a breathing space, set my teeth, and again grappled fiercely, wrist and knee, with the machine. It gave under my desperate onset and turned over. It struck my chin violently. One hand on the saddle, the other on the lever, I stood panting heavily in attitude to mount again.

" But with this recovery of a prompt retreat my courage recovered. I looked more curiously and less fearfully at this world of the remote future. In a circular opening, high up in the wall of the nearer house, I saw a group of figures clad in rich soft robes. They had seen me, and their faces were directed towards me.

" Then I heard voices approaching me. Coming through the bushes by the White Sphinx were the heads and shoulders of men running. One of these emerged in a pathway leading straight to the little lawn upon which I stood with my machine. He was a slight creature—perhaps four feet high—clad in a purple tunic, girdled at the waist with a leather belt. Sandals or buskins—I could not clearly distinguish which—were on his feet ; his legs were bare to the knees, and his head was bare. Noticing that, I noticed for the first time how warm the air was.

" He struck me as being a very beautiful and graceful creature, but indescribably frail. His flushed face reminded me of the more beautiful kind of consumptive—that hectic beauty of which we used to hear so much. At the sight of him I suddenly regained confidence. I took my hands from the machine."

H. G. WELLS

NOTES

The Chemical History of a Candle. From "The Chemical History of a Candle," by Michael Faraday.

Michael Faraday (1791–1867), starting life as a bookbinder's apprentice, became one of the most famous scientists of the nineteenth century. As a youth he was attracted by Sir Humphry Davy's lectures on natural philosophy, and finally entered his service as an assistant in the laboratory of the Royal Institution. With Davy, Faraday travelled across Europe and met the leading scientists of his day. Eventually he gave lectures of his own and became famous for his researches in the transformation of energies, magnetism and electricity, and the condensation of gases into liquids. In all these matters his mind was attracted by the philosophy of the principles involved, and it was left to his successors to adapt these discoveries to the practical purposes of everyday life. His "Lectures on the Chemical History of a Candle" were given for a number of years to the juvenile audiences at the Royal Institution. As a scientist he believed in the habit of trying to form "clear and precise ideas"; as a writer he attempted to convey those ideas in "clear and definite language."

Soda-water. From "Chats on Science," by Edwin E. Slosson, Ph.D.

Edwin E. Slosson, Director of Science Service, Washington, and author of several popular books of science, is typical of the school of writers who of recent years have attempted to cater for the increasing demand among both the young and adults for scientific literature of a non-technical kind. Slosson realises that genuine scientific research entails much hard thinking, but maintains that the popular explanation of what the scientist has achieved often makes pleasant reading.

"Road-making is hard, but joy-riding is not." "Chats on Science" contains an amazingly attractive variety of subjects, embracing such different themes as "Perfumes from Poison Gas," "Artificial Silk," "The Pop-over Stars," "The Fight against the Potato," "Shark-Towed Submarines," and "Smashing Up Atoms." All are treated in the same easy manner as is displayed in the "Chat" on "Soda-Water."

P. 10, l. 25. *It is a hang-over word :* See Ruskin, "Sesame and Lilies," where in his lecture entitled "Of Kings' Treasuries" he says : "There are masked words droning and skulking about us in Europe just now—(there never were so many, owing to the spread of a shallow, blotching, blundering, infectious 'information,' or rather deformation, everywhere, and to the teaching of catechisms and phrases at schools instead of human meanings)—there are masked words abroad, I say, which nobody understands, but which everybody uses, and most people will also fight for, live for, or even die for, fancying they mean this, or that, or the other, of things dear to them : for such words wear chameleon cloaks—'ground-lion' cloaks, of the colour of the ground of any man's fancy : on that ground they lie in wait, and rend him with a spring from it. There were never creatures of prey so mischievous, never diplomatists so cunning, never poisoners so deadly, as these masked words ; they are the unjust stewards of all men's ideas : whatever fancy or favourite instinct a man most cherishes, he gives to his favourite masked word to take care of for him ; the word at last comes to have an infinite power over him,—you cannot get at him but by its ministry. And in languages so mongrel in breed as the English, there is a fatal power of equivocation put into men's hands, almost whether they will or no, in being able to use Greek or Latin forms for a word when they want it to be respectable, and Saxon or otherwise common forms when they want to discredit it."

ll. 25–26. "*Sardines*" *that never saw Sardinia :* Sardines are the young of the pilchard and are caught in the Mediterranean, around the Norwegian coasts, and off the coasts of Britain and Brittany.

l. 26. "*Bologna*" *:* the famous Italian city, capital of the province of Bologna, renowned for its "Bologna" sausage.

P. 12, l. 32. *Yankee:* a resident of the New England States. Supposedly a corruption of the word "English" by the Indians.

P. 13, l. 16. *A nickel:* U.S. five-cent piece.

P. 15, l. 9. *Faucet:* a barrel tap.

A Piece of Chalk. From "Lectures and Lay Sermons," by Thomas Huxley.

Thomas Henry Huxley (1825–1895) began life as a medical student, and after passing his various examinations with distinction, was gazetted as surgeon to H.M.S. "Rattlesnake" engaged on surveying work in Torres Strait. While in these tropical seas Huxley carried out important investigations in zoological science. On his return to England in 1850 he was elected Fellow of the Royal Society as a mark of recognition for the important contributions he had made to scientific learning. In 1854 he was appointed lecturer at the School of Mines and as naturalist assisted in the geographical survey of the following year. He showed later tremendous interest in Darwin's theory of evolution and used his knowledge of geology in support of it. The philosophical significance of the findings of science was the factor which principally attracted Huxley, and during the latter part of his life he devoted much time to presenting valuable evidence on such matters to various Royal Commissions. His broad-minded principles were largely responsible for a gradual widening of horizons in the teaching of science in English schools. Much of his importance as a scientist is due to the effectiveness with which he was able to express his opinions in the many contributions he made to various scientific journals.

P. 19, l. 19. *Albion:* the most ancient name used for the British Isles and particularly for England. The Romans connected it with *albus*, white, in reference to the white cliffs of Dover.

P. 20, l. 33. *Cormorant:* a large web-footed sea-bird, remarkable for its ability to swim under water and capture fish.

l. 37. *The Lebanon:* the central mountain mass of Syria. The name is derived from the Semitic *laban*, meaning "whitish," and no doubt refers to their chalk or limestone formation.

P. 21, ll. 30–32. *Than the most learned student who is deep read*

in the records of humanity: Compare Wordsworth's poem, "The Tables Turned":—

"Up! up! my Friend, and quit your books;
Or surely you'll grow double:
Up! up! my Friend, and clear your looks;
Why all this toil and trouble?

The sun, above the mountain's head,
A freshening lustre mellow
Through all the long green fields has spread,
His first sweet evening yellow.

Books! 'tis a dull and endless strife:
Come, hear the woodland linnet,
How sweet his music! on my life,
There's more of wisdom in it.

And hark! how blithe the throstle sings!
He, too, is no mean preacher:
Come forth into the light of things,
Let Nature be your teacher.

She has a world of ready wealth,
Our minds and hearts to bless—
Spontaneous wisdom breathed by health,
Truth breathed by cheerfulness.

One impulse from a vernal wood
May teach you more of man,
Of moral evil and of good,
Than all the sages can.

Sweet is the lore which Nature brings;
Our meddling intellect
Mis-shapes the beauteous forms of things:—
We murder to dissect.

Enough of Science and of Art;
Close up those barren leaves:
Come forth, and bring with you a heart
That watches and receives."

P. 22, l. 26. *Stalagmites and stalactites:* the deposits of carbonate of lime which form on the floor and roof of a cave respectively.

P. 23, l. 4. *Laminated:* split up into layers or leaves.

l. 9. *Matrix:* Place in which a thing is produced or developed—a mass of rock enclosing gems, etc.—or the substance between cells.

l. 27. *Calcareous :* (more correctly " calcarious ") ; containing carbonate of lime or limestone.
l. 37. *Spoor :* track or scent of an animal.
P. 24, l. 9. *Arborescent :* tree-like.
P. 25, l. 21. *Tar :* a sailor, from tarpaulin, the sailor's tarred or oiled hat.
P. 27, l. 25. *Friable :* easily crumbled.
P. 28, l. 14. *Filamentous :* fibre-like.
l. 15. *Amorphous :* shapeless, unorganised.
P. 29, l. 3. *Diatomaceae :* microscopic plant growths at the bottom of the sea forming fossil deposits.
P. 30, l. 37. *Animalculae :* microscopic animals.
P. 31, l. 23. *Cretaceous :* of chalk.
ll. 31–32. *Sir Charles Lyell :* author of " Elements of Geology," from which the passage quoted in the following paragraph is taken.
P. 32, l. 9. *Echinus :* the sea-urchin.
P. 33, l. 26. *Syenite :* grey crystalline rock of feldspar and hornblende with or without quartz.
P. 34, ll. 29–30. *The whirligig of time :* " The whirligig of time brings in his revenges."—Shakespeare, " Twelfth Night," Act V.
P. 35, l. 30. *Sinai and Ararat :* the first the name of the mountain where Moses received the Commandments, and the second where Noah's Ark came to rest.
P. 37, ll. 20–21. *The pterodactyl, the ichthyosaurus, and the plesiosaurus :* all now extinct ; a winged reptile, a huge marine animal with large head, tapering body, four feet, and a long tail, and a marine reptile with long neck, short tail, and four large paddles, respectively.
P. 38, l. 2. *Foraminiferae :* minute shell-fish.

Old Red Sandstone. From " The Old Red Sandstone," by Hugh Miller.

Hugh Miller (1802–1856), of humble birth, eventually became one of the foremost Scottish geologists. He commenced work as a stone-mason and travelled to various parts of Scotland in pursuit of his occupation. Miller took a deep and studious interest in the rock formations in which he laboured. He had also a natural urge to write, and published some verses and later a number of prose essays. It was the virile style of these latter which first attracted public attention. In 1834 he left the business of stonemasonry and was offered an appointment in the Commercial Bank of

Scotland. In 1835 he published his "Scenes and Legends of the North of Scotland, or the Traditional History of Cromarty." During these years he was still busily engaged in the collecting of geological specimens, and after his marriage in 1837 gave himself up entirely to the study of the subject. For the remainder of his life he continued to study and to write on both geological and theological matters. For a time he was editor of the new Whig Edinburgh newspaper, "The Witness," in which he commenced his articles on "The Old Red Sandstone." Here again his earnest and sincere style won him a remarkable following. "The Old Red Sandstone" was first published in book form in 1841. Another popular work, "My Schools and Schoolmasters," appeared in 1854. He died in 1856, and in 1902 the centenary of his birth at Cromarty was attended by scientific representatives from all over the world.

P. 39, l. 2. *Last February :* Miller commenced his articles on "The Old Red Sandstone" in "The Witness" in 1840.

ll. 9–10. *Twa Dogs :* one of Robert Burns' early satirical poems, in which two dogs, one Caesar, a laird's dog, and the other Luath, "a ploughman's collie," contrast the ways in which the gentry and the crofters pass their lives. The poem is a fable in the manner of Aesop, but gives expression to Burns' warm-hearted sympathy with the crofter's life and his intolerance of the excesses of the gentry.

Caesar wonders how the cotters can contrive to live at all, and Luath agrees that ditching, dyke-building, "baring a quarry, and sic like," are unattractive means of eking out an existence.

l. 23. *Frith :* another form of "firth," meaning an arm of the sea or an estuary.

l. 27. *Diluvial :* a term used to describe deposits formed by the flood-like agency of water, to contrast them with alluvial matter formed by slow and steady water agencies.

P. 41, l. 6. *Blink of rest :* Burns' "The Twa Dogs," wherein Luath says of the peasant : "A blink o' rest's a sweet enjoyment."

l. 24. *Plummet :* Plumbline or sounding lead.

P. 43, l. 28. *Gneiss :* a rock formation consisting of quartz and felspar.

Horn-blende : a dark brown, black, or green mineral and a constituent of granite and other minerals.

l. 34. *Lignites :* imperfectly formed coal—usually showing original wood structure.

Lias : the lowest group of Jurassic strata.

P. 44, l. 1. *Hyperstenes :* more correctly hypersthenes, a rock-forming mineral containing iron.

Porphyries : a hard rock formation composed of crystals of white or red felspar in red groundmass.

l. 2. *Micaceous schists :* rock formations containing mica-like plates.

l. 16. *Volutes :* the spiral scrolls at the top of an architectural column.

ll. 17–18. *The far-famed walnut of the fairy tale :* Is Miller thinking of the Comtesse D'Aulney's fairy story of "The White Cat" (1682) wherein the White Cat helped the youngest prince of a certain king to succeed in his quest of finding a web of cloth which would pass through the eye of a fine needle? "The prince . . . took out of his box a walnut, which he cracked . . . and saw a small hazel nut, which he cracked also . . . and found therein a kernel of wax. . . . In this kernel of wax was hidden a single grain of wheat, and in the grain a small millet seed. . . . On opening the millet, he drew out a web of cloth, 400 yards long, and in it was woven all sorts of birds, beasts, and fishes, fruits and flowers, the sun, moon, and stars, the portraits of kings and queens, and many other wonderful designs."

l. 25. *Bivalves :* hinged double shell fish.

Striated : striped or scored.

ll. 36–37. *Of sovereign efficacy :* of chief or supreme power or worth.

P. 45, l. 8. *Skerries :* rugged rocks covered by the sea at high water or in stormy weather.

l. 21. *Herbarium :* a dried collection of plants arranged so as to exhibit their individual characteristics.

ll. 22–23. *Scallops, and gryphites, and ammonites :* types of shell-fish.

l. 25. *Belemnite :* tapering fossil bone of extinct cuttle-fish.

l. 37. *Aerolites :* meteorites.

Coral Formations. From "The Voyage of the Beagle," by Charles Darwin.

Charles Robert Darwin (1809–1882), after graduating at Cambridge, sailed as naturalist on the "Beagle" on

the famous surveying expedition of 1831–1836. "The Beagle" visited Cape de Verde, the Atlantic Isles, the South American Coast, Tahiti, New Zealand, Australia, Tasmania, St. Helena, Ascension Isle, Brazil, and the Azores. Darwin found upon his return that the material he had collected in his note-books was matter sufficient for careful thought and classification for many years. The principal factors which engaged his attention were the connection between the animal species of the various continents and the apparent links between past and present species. These thoughts culminated in the famous "Origin of Species," first published in 1839, and which immediately became the most widely discussed treatise of the nineteenth century.

P. 47, l. 6. *April 1st:* 1836.

ll. 6–7. *Keeling of Cocos Islands:* a group of coral islands in the Indian Ocean. There are altogether twenty-three small islands, nine and a half miles being the greatest width of the whole atoll.

P. 48, l. 26. *Gannets:* solan geese, large sea fowl resembling the goose, frequenting in the British Isles the Bass Rock, Ailsa Craig, St. Kilda, and Lundy Isle.

Frigate-birds: so called by British sailors on account of their swiftness of flight and their habit of cruising round and even pursuing larger sea-birds.

P. 50, l. 11. *Zoophytes:* plant-like animals such as star-fish, jelly-fish, sea anemones, etc.

P. 52, l. 1. *Chama:* a large double-shelled sea fish.

P. 55, l. 8. *Chamisso:* Albert Von Chamisso (1781–1838), a German poet and botanist.

P. 57, l. 36. *New Caledonia:* an island in the West Pacific Ocean belonging to France.

P. 58, ll. 3–4. *The Society Archipelago:* an archipelago of the Pacific Ocean, belonging to France, the principal island being Tahiti.

P. 65, l. 32. *The Maldiva Archipelago:* an archipelago of coral islets in the Indian Ocean.

P. 69, l. 16. *The Chagos group:* a group of atolls in the Indian Ocean belonging to Britain and disposed in a circle round the Chagos bank.

Martins and Swallows. From "The Natural History of Selborne," by Gilbert White.

Gilbert White (1720–1793), born in the little Hampshire

village of Selborne, and after leaving the University of Oxford, entered the Church and spent the rest of his days in or near his native hamlet. He led the quiet unpretentious life of the average English clergyman in a typical rural village of the south, and history would have had little more to say of him had it not been that he combined a delightfully simple and gracious style of writing with a careful and detailed observation of the Nature lore he found around him. White shared his interest in rural life with a number of scientific friends and relatives with whom he frequently corresponded, evolving thereby that easy, natural style typical of the letter-writer at his best. Eventually he set down his observations in his now famous "Natural History of Selborne," hoping that in consequence others might be encouraged to attempt a similar series of observations on other interesting localities in rural England. The book was well received when it first appeared in 1789 and has remained popular ever since. Its continued success is due to White's careful but unpretentious observation of Nature and that simple, homely conversational style of writing which gives us so much insight into his own quaint and charming personality. As a work of science it stands somewhere between the highly imaginative and superstitious utterances of mediaevalism and the more carefully detailed scientific observations of the eighteenth and nineteenth centuries. In it White accomplished for the English countryside what Walton achieved for the piscatorial art in "The Compleat Angler."

P. 75, l. 5. *Monography:* a separate writing on a single subject.
 l. 8. *Hirundines:* swallows.
 l. 14. *Nidification:* nest-building.
P. 79, l. 5. *Aits:* small islands.
 l. 19. *Congeners:* members of the same class or kind.
P. 80, l. 8. *Hybernaculum:* winter quarters.
P. 82, l. 16. *Mandibles:* upper and lower parts of the beak.
 l. 18. *Excubitor:* sentinel.
P. 83, l. 11. *Coleoptera:* a variety of beetle whose front wings sheath the hinder ones.
P. 84, l. 35. *Cunabula:* cradles.
 Terebrates: bores.
P. 85, l. 25. *Rerum prudentia:* prudence.
 l. 26. *Latebrae:* hiding-places.

P. 86, l. 5. *Cryptogame :* secret in their habits of breeding.

ll. 36–37. *For there are few towns or large villages but what abound with house-martins :* See Banquo's description of Macbeth's castle in " Macbeth," I. VI. :—

" This guest of summer,
The temple-haunting martlet, does approve,
By his lov'd mansionry, that the heaven's breath
Smells wooingly here : no jutty, frieze,
Buttress, nor coign of vantage, but this bird
Hath made his pendent bed and procreant cradle :
Where they most breed and haunt, I have observed,
The air is delicate."

P. 90, l. 9. *Aurelia :* chrysalis of an insect.

P. 93, l. 9. *A genus per se :* a class by itself.

l. 26. *στοργή :* parental love.

Gossamer.

P. 96, l. 22. *Apterous :* wingless.

Crickets.

P. 99, ll. 25–26. *Filling their minds with a train of summer ideas :* Compare with this Wordsworth's theory of recollection in " To the Cuckoo," in which the following two stanzas occur :—

" Though babbling only to the Vale
Of sunshine and of flowers,
Thou bringest unto me a tale
Of visionary hours,"

and

" And I can listen to thee yet ;
Can lie upon the plain
And listen, till I do beget
That golden time again."

The same idea is expressed again in Wordsworth's poem about the daffodils beginning " I wandered lonely as a cloud," and in which he concludes :—

" For oft when on my couch I lie
In vacant or in pensive mood,
They flash upon that inward eye
Which is the bliss of solitude ;
And then my heart with pleasure fills,
And dances with the daffodils."

The same theory of recollection is even more elaborately explained in Wordsworth's famous " Lines Composed Above Tintern Abbey."

P. 100, l. 19. *Milton's "Il Penseroso":* "Il Penseroso" and "L'Allegro," two early and complementary poems by Milton describing two different moods in the poet's life. See also the title of one of Charles Reade's novels, "The Cricket on the Hearth."

P. 101, l. 4. *The dog-days:* the hottest time of the year; supposedly when the Dog-star was in the ascendant.

P. 102, l. 6. *Pharaoh's plague of frogs:* Exodus viii. 3.

l. 36. *Legumes:* vegetables.

The Pageant of Summer. From "The Life of the Fields," by Richard Jefferies.

Richard Jefferies (1848–1887) combined a rare ability to observe Nature with a real facility in prose-writing. He spent the whole of his short life in close contact with the English countryside, and wrote almost exclusively of it during his journalistic career. His principal works are "A Game Keeper at Home," "The Story of my Heart," "Wild Life in a Southern County," "Wood Magic," and "The Life of the Fields." As a writer he owes his charm to the ease with which he was able to convey his rich experience of natural phenomena to the mind of his reader.

P. 104, l. 24. *Angelica:* a fragrant plant used in cookery and medicine.

P. 105, l. 3. *Umbelliferous:* types of plants whose flower clusters spring from a common centre and on stalks nearly equal in length spread out to form a flat, convex, or concave surface, as in a "head" of parsley.

l. 5. *A bitter greenish scent:* It is not uncommon to find writers associating particular colours with particular scents.

P. 106, l. 8. *Alchemic:* capable of effecting a change.

l. 24. *Prismatic gleam:* as if distributed or formed by a prism.

P. 107, l. 36. *Sorrel:* an acid-leaved herb of the dock family.

P. 109, l. 3. *A shrike:* a strong hooked and toothed billed bird which impales its prey of small birds and insects on thorns.

A redstart: a common singing bird with a red tail which it moves quickly from side to side.

l. 18. *Landrails:* corn-crakes.

P. 110, l. 11. *Just tremble at the extreme edge of hearing:* See Keats's "On a Summer's Day":—

"I stood tiptoe upon a little hill,
The air was cooling, and so very still,
That the sweet buds which with a modest pride
Pull droopingly, in slanting curve aside,
Their scantly leaved, and finely tapering stems,
Had not yet lost those starry diadems
Caught from the early sobbing of the morn.
The clouds were pure and white as flocks new shorn,
And fresh from the clear brook ; sweetly they slept
On the blue fields of heaven, and then there crept
A little noiseless noise among the leaves,
Born of the very sigh that silence heaves."

And again in the same poem :—

"How silent comes the water round that bend ;
Not the minutest whisper does it send
To the o'erhanging sallows."

l. 33. *Membranes* : thin animal tissue.

P. 111, l. 26. *Polynesia :* small islands in the Pacific Ocean east of Australia.

P. 112, l. 29. *Skep :* straw or wicker beehive.

l. 30. *Saccharine :* a sweet substance obtained from coal-tar and often used in place of sugar for sweetening.

P. 114, l. 10. *Kestrel :* a small species of hawk.

P. 115, l. 8. *Columnar :* column-like.

P. 117, l. 18. *Lychnis :* a red type of flower including campion and ragged robin.

l. 22. *Loosestrife :* a tall upright plant growing in moist places.

l. 23. *Comfrey :* a tall plant with clusters of whitish or purplish bells ; favours ditches.

l. 27. *Beechmast :* fruit of the beech tree.

P. 118, l. 12. *Charlock :* field mustard.

l. 25. *Leverets :* young hares.

l. 28. *Coombe :* a short valley on the flank of a hill or running up from the coast.

l. 31. *Knapweed :* a common weed with hard stem and light purple flowers.

P. 119, l. 4. *Bryony :* a climbing plant.

l. 6. *Burdock :* a coarse plant with prickly flower-heads and dock-like leaves.

l. 15. *Pewterwort :* so named because of its use in polishing pewter utensils.

P. 120, l. 19. *Enamelled beneath the feet :* In "Arcadia" (1580–1581) Sir Philip Sidney speaks of fields "enamelled with all sorts of eye-pleasing flowers."

P. 124, l. 20. *Phidias :* the famous Greek sculptor.

Mind Under Water.

There are not many men of letters who have been able to penetrate the mind of the fish. Compare Rupert Brooke's poem, " The Fish," beginning :—

" In a cool curving world he lies
And ripples with dark ecstasies.
The kind luxurious lapse and steal
Shapes all his universe to feel
And know and be ; the clinging stream
Closes his memory, glooms his dream,
Who lips the roots o' the shore, and glides
Superb on unreturning tides.
Those silent waters weave for him
A fluctuant mutable world and dim,
Where wavering masses bulge and gape
Mysterious, and shape to shape
Dies momently through whorl and hollow,
And form and line and solid follow
Solid and line and form to dream
Fantastic down the eternal stream ;
An obscure world, a shifting world,
Bulbous, or pulled to thin, or curled,
Or serpentine, or driving arrows,
Or serene slidings, or March narrows."

P. 124, l. 30. *Jack :* small pike.

P. 130, l. 9. *Knobkerrie :* a weapon used by South African tribes and formed of a short stick with knobbed head.

P. 136, l. 20. *Depend :* hang down.

Observations on the Common Eel. By J. T. Cunningham. This paper was contributed to " Nature," a leading scientific journal, in February 1924.

P. 137, l. 23. *The propagation of the eel was a mystery :* Compare the testimony of Izaak Walton, who, in " The Compleat Angler " writes as follows: " It is agreed by most men, that the eel is a most dainty fish : the Romans have esteemed her the Helena of their feasts ; and some the queen of palate-pleasure. But most men differ about their breeding : some say they breed by generation, as other fish do ; and others, that they breed, as some worms do, of mud ; as rats and mice, and many other living creatures, are bred in Egypt, by the sun's heat, when it shines upon the overflowing

of the river Nilus ; or out of the putrefaction of the earth, and divers other ways."

P. 140, ll. 9–10. *On the banks of the Severn :* Again compare Walton, who says : " I have seen, in the beginning of July, in a river not far from Canterbury, some parts of it covered over with young eels, about the thickness of a straw ; and these eels did lie on the top of that water, as thick as motes are said to be in the sun : and I have heard the like of other rivers, as namely, in Severn, where they are called yelvers ; and in a pond, or mere, near unto Staffordshire, where, about a set time in summer, such small eels abound so much, that many of the poorer sort of people that inhabit near to it, take such eels out of this mere with sieves or sheets, and make a kind of eel-cake of them, and eat it like as bread." The " Compleat Angler " was first published in 1653.

The Alligators of Guiana. From " Tropical Wild Life in British Guiana," vol. i., edited by William Beebe and others, with a preface by Theodore Roosevelt and published by the New York Zoological Society in 1917.

" Tropical Wild Life in British Guiana " was written by a party of scientists sent to the Tropical Research Station in British Guiana by the New York Zoological Society. The professed object of the book is not merely an intensive system of cataloguing, but rather to provide a readable account of a period of intensive study spent in a district teeming with natural life. " The best scientific books," says the preface, " are those which possess such vision and are so interesting to intelligent laymen that they are often to be found in the libraries of cultivated people who are not professed scientists."

A further extract from this book will be found on page 187.

P. 145, l. 26. *Saurians :* the classes of lizards which include crocodiles, alligators, and the extinct ichthyosaurus and plesiosaurus.

P. 148, l. 28. *Autochthonous :* native to the soil.

P. 150, l. 19. *Pigment :* the colouring matter of the tissue.

Spinning Tops and *The Boomerang.* From " Mechanics and Some of its Mysteries," by V. E. Johnson.

" Mechanics and Some of its Mysteries " is one of a series of books called " Playbooks of Science " intended to

provide boys with intelligent amusement on scientific subjects. It is typical of the desire of scientists to make science popular and attractive even to the youngest.

P. 156, l. 34. *Centrifugal :* a tendency to fly from the centre.

P. 157, l. 8. *Torsion :* a state of being spirally twisted.

l. 19. *Cohesion :* the force with which particles of a body stick together.

P. 159, l. 18. *Vortex :* a whirling motion or mass.

P. 160, l. 30. *Teetotum :* a small top, a toy.

A Scientist's Hut in the Antarctic. From " Scott's Last Expedition, the Personal Journals of Captain R. F. Scott, R.N., C.V.O., on his Journey to the South Pole."

Captain Scott of the Royal Navy (1868–1912) commanded the National Antarctic Expedition of 1900–1904 and was successful in completing discoveries of the utmost importance in Antarctic Exploration. In June 1910 he sailed in the " Terra Nova " with a second party, " the most completely equipped expedition for scientific purposes connected with the Polar regions, both as regards men and material, that ever left these shores." This time his object was twofold, to continue in greater detail the scientific research and observations begun on the previous expedition and to reach the South Pole itself. In January 1911 winter quarters were established at Cape Evans. This is the hut which is described in this extract from Captain Scott's journals. The journey to the Pole and the uncompleted return have since become epics of history. Scott showed great care in laying a train of supply depots along his route. The polar party with supporting parties left Hut Point on McMurdo Sound in November 1911. The last supporting party turned in their tracks on January 4, 1912, leaving Scott, Bowers, Evans, Oates, and Wilson to complete the last 150-mile dash to the pole as a five-man unit. They reached the pole on January 18th, only to find that Amundsen, the Norwegian explorer, had forestalled them on December 15th. Scott had now 800 miles to cover on the return journey. Bad weather delayed them and every member of the party perished. Evans died from concussion of the brain on February 17th. Oates, on March 17th, when frost-bites rendered him incapable of travelling further,

walked out of their tent into a blizzard rather than delay his companions, and on March 29th the remainder of the party perished when only 11 miles from One Ton Depot and just over 100 miles from their base at Cape Evans.

N.B.—The parts of the narrative in inverted commas are not from the original journal which Scott kept but from relevant private letters.

P. 169, l. 3. *Tuesday, January 10th:* 1911.

P. 170, l. 9. *Compressed forage bales:* for the ponies.

l. 28. *Campbell:* Lieutenant Victor L. A. Campbell, R.N.

P. 171, l. 3. *Skua:* a large gull.

l. 22. *Simpson's Corner:* George C. Simpson, D.Sc., meteorologist; in his part of the hut were the meteorological instruments.

l. 28. *The depot journey:* for the putting down of supplies along the route to be followed later in the journey to the Pole.

l. 29. *Bowers:* Henry R. Bowers, Lieutenant, Royal Indian Marines, who perished with Scott and Wilson at the last camp.

l. 33. *Hut Point:* near Cape Armitage.

Meares: Cecil H. Meares had charge of the dogs.

P. 172, l. 13. *Wright:* Charles S. Wright, B.A., physicist.

P. 173, l. 16. *Day:* Bernard C. Day, motor engineer.

Nelson: Edward W. Nelson, biologist.

l. 19. *Debenham:* Frank Debenham, B.A., B.Sc., geologist.

Taylor: T. Griffith Taylor, B.A., B.Sc., B.E., geologist.

Gran: Tryggve Gran, Sub-Lieutenant, Norwegian N.R., B.A., ski expert.

P. 174, l. 12. *Clissold:* Thomas Clissold, cook, late R.N.

l. 17. *Hooper:* F. J. Hooper, steward, late R.N.

l. 20. *Anton:* Anton Omelchenko, groom.

Demetri: Demetri Gerof, dog driver.

P. 175, ll. 4–5. *Cape Evans:* in McMurdo sound.

l. 5. *Erebus:* The name given to the South Polar mountain by Ross, the discoverer.

l. 18. *Ponting:* Herbert G. Ponting, F.R.G.S., camera artist.

P. 176, l. 12. *P.O. Evans:* Edgar Evans, Petty Officer, R.N., who formed one of the final polar party and died on the return journey at the foot of the Beardmore Glacier.

P. 177, l. 16. *Crean :* Thomas Crean, Petty Officer, R.N.
l. 20. *Rennick :* Henry E. de P. Rennick, Lieutenant, R.N., one of the ship's company.
P. 181, l. 30. *Parasitologist :* one who investigates parasites ; in this case Atkinson.
l. 31. *Sunny Jim :* Simpson.
P. 183, ll. 3–4. *Sent back in the ship :* when it left on January 25th.
P. 185, l. 37. *Lashly :* W. Lashly, Chief Stoker, R.N., a member of the final supporting party which accompanied Scott to within 150 miles of the Pole.
P. 186, l. 5. *Cribbers :* crib-biters.

Research in a Tropical Jungle. From " Tropical Wild Life in British Guiana," vol. i., edited by William Beebe and others. (See note on page 294.)

P. 187, l. 21. *Seines :* nets.
P. 188, l. 5. *Termites :* white ants.
P. 189, l. 17. *Rufous :* reddish-brown.
P. 191, l. 3. *Scarabs :* a species of beetle.
l. 36. *Manakin :* a small gaily coloured bird.
P. 192, l. 7. *Hoatzins :* or houctzins, so called by the natives on account of the harsh grating hiss which these birds make.
l. 9. *Habitat :* natural home.
l. 11. *Cursorial :* running.
l. 12. *Volant :* flying.
l. 13. *Vampires :* a species of bat.
P. 193, l. 11. *Tinamou :* a quail-like game-bird.

The Study of Astronomy. From " The Universe Around Us," by Sir James Jeans, M.A., D.Sc., LL.D., F.R.S.

Sir James Jeans is one of the most famous present-day mathematicians and astronomers. After a brilliant mathematical career at Cambridge, he became Stokes lecturer in applied mathematics. In 1919 he was awarded the Royal Medal of the Royal Society. His two most popular books have been " The Universe Around Us " and " The Stars in their Courses." He has also broadcast several series of popular lectures on astronomy.

" ' The Universe Around Us,' " he says, " contains a brief account, written in simple language, of the methods and results of modern astronomical research, both observational and theoretical. . . . My ideal,

perhaps never wholly attainable, has been that of making the entire book intelligible to readers with no special scientific knowledge."

P. 197, l. 3. *Galileo Galilei :* Galileo (1564–1642), the great Italian astronomer, famous as the discoverer of the law of the pendulum and for the construction of the first telescope. Milton refers to this latter invention in Book I. of " Paradise Lost " when describing the broad shield of the fallen archangel, Satan :—

" He scarce had ceased when the superior Fiend
Was moving toward the shore ; his ponderous shield,
Ethereal temper, massy, large, and round,
Behind him cast. The broad circumference
Hung on his shoulders like the moon, whose orb
Through optic glass the Tuscan artist views
At evening, from the top of Fesole,
Or in Valdarno, to descry new lands,
Rivers, or mountains, in her spotty globe."

Although Galileo was born at Pisa in Tuscany, he spent the latter part of his life in or near Florence. Fesole is a hill outside Florence. Valdarno, or the valley of the river Arno, was where Galileo had a residence.

In the prose tract, the " Areopagitica," Milton speaks of Galileo again and says : " There (in Italy) it was I found and visited the famous Galileo, grown old, a prisoner to the Inquisition for thinking in astronomy otherwise than the Franciscan and Dominican Licensers thought."

An interesting and romantic link with the great astronomer was forged in 1933 when the light of a star collected through the lens of Galileo's telescope was by means of wireless made to switch on the lights of a scientific exhibition in Chicago.

l. 6. *Roger Bacon :* 1214–1294. The mediaeval scientist —called Friar Bacon in contemporary literature—held to be possessed of remarkable gifts. The discovery of gunpowder, the air pump, and the telescope are sometimes attributed to him.

l. 28. *Doge and the Senate :* the chief magistrate, and along with the Senate the virtual ruler of ancient Venice.

P. 198, l. 10. *Pythagoras :* the famous Greek mathematician and philosopher who propounded the doctrine of the transmigration of souls from men to animals or animals to men.

Philolaus : a Greek philosopher who followed the teaching of Pythagoras.

l. 21. *Ptolemy :* a celebrated mathematician, astronomer, and geographer. His astronomical theories regarded the earth as the immovable centre of the Universe, and Milton the English poet accepted this convention in "Paradise Lost."

P. 199, l. 5. *Giordano Bruno :* the Italian philosopher of the Renaissance (1548–1600), who conceived God as reconciling spirit and matter.

P. 200, l. 8. *And now Galileo catches Jupiter :* Notice the dramatic change of tense.

P. 201, l. 7. *Kepler :* 1571–1630. The German astronomer on whose laws of planetary motion Newton based much of his work.

ll. 34–35. *Could not keep their heads buried :* Cf. the almost proverbial accounts of the ostrich's attempts to hide itself.

P. 202, l. 24. *Bede :* the "Venerable" Bede (673–735), historian and scholar. Spent most of his life at Jarrow, but his bones were removed to Durham Cathedral in the eleventh century.

P. 205, l. 17. *Nebulae :* clusters of stars.

l. 28. *Electrons :* electric charge contained by atoms.

Man's Place in the Universe. From "The Nature of the Physical World," by Sir A. S. Eddington.

Professor A. S. Eddington, M.A., LL.D., D.Sc., is the Plumian Professor of Astronomy in the University of Cambridge and, like Sir James Jeans, has done much to popularise the study of modern science.

P. 211, l. 6. *Extrapolation :* a system of calculating a result by an already known series of results.

P. 213, l. 13. *The Cepheid variables :* a constellation, some stars of which vary periodically in brightness.

l. 32. *The hierarchy :* a series of ranks or grades.

P. 214, l. 30. "*Behold the throne of chaos . . .*" *:* Milton, "Paradise Lost," Book II.

P. 215, ll. 21–22. *The sidereal universe :* the universe of stars.

l. 27. *Lucid stars :* stars visible to the naked eye.

P. 216, l. 15. *Sub-atomic :* formed by the constituent parts of the atom.

P. 217, l. 5. *Palaeontologists :* those who study extinct animals and plants, *i.e.* fossils.

P. 218, l. 19. *Satellite :* a small or secondary planet revolving round a larger one.

P. 222, l. 25. *Fission* : the act of splitting or dividing into pieces.

l. 32. *Hypothesis :* supposition or conjecture.

l. 33. *Laplace :* 1749–1827. French mathematician and astronomer.

The Theory of Relativity. From " Relativity, the Special and the General Theory, a Popular Exposition," by Albert Einstein, Ph.D., translated by Robert W. Lawson, D.Sc.

Albert Einstein, born 1879 of German-Jewish parents, educated in Germany and Switzerland, is famous as the exponent of the theory of relativity. The extracts quoted in this section of the book are taken from Dr. Robert W. Lawson's translation of Einstein's own popular exposition of Relativity and outline the principal factors on which the theory is based.

" . . . the position of Einstein's theory is that the question of a unique right frame of space does not arise. There is a frame of space *relative* to a terrestrial observer, another frame relative to the nebular observers, others *relative* to other stars. Frames of space are relative. Distances, lengths, volumes—all quantities of space-reckoning which belongs to the frames—are likewise relative. A distance as reckoned by an observer on one star is as good as the distance reckoned by an observer on another star. We must not expect them to agree ; the one is a distance relative to one frame, the other is a distance relative to another frame. Absolute distance not relative to some special frame is meaningless.

" The next point to notice is that the other quantities of physics go along with the frame of space, so that they also are relative."—EDDINGTON, " The Nature of the Physical World."

P. 229, l. 2. *Our old friend the railway carriage :* frequently used as a term of reference in Einstein's " Relativity, a Popular Exposition."

Cloud Forms and Painting. From " Modern Painters," by John Ruskin.

John Ruskin (1819–1900) was both artist and writer and spent his life in an attempt to prove to his generation, by his writings and by his lectures, that the true

principles of art are founded on the truths of Nature, and that the practising of these truths is the only safe guide for the individual and the social state. He was himself an accomplished artist and his sequence of volumes under the title of " Modern Painters " did much to justify the artists of his day in the eyes of his contemporaries.

P. 241, ll. 29–30. *He ceases to feel them if he be always with them :* Notice the controversy Wordsworth and Coleridge had on this subject. Wordsworth claimed that the simple rustic was much affected by the beauty amongst which he lived and states in the poem " Michael " :—

" And grossly than man errs who should suppose
That the green valleys and the streams and rocks
Were things indifferent to the shepherd's thoughts."

Coleridge, however, believed differently and wrote in the " Biographia Literaria " : " . . . the ancient mountains, with all their terrors and all their glories, are pictures to the blind, and music to the deaf."

P. 243, l. 29. *Azote :* nitrogen.

P. 244, l. 25. " *The Excursion* " *:* Wordsworth's longest and most philosophical poem.

l. 33. " *American Notes* " *:* an account of Dickens' visit to America in 1842. The passage referred to is as follows : " the lazy motion of the boat, when one lay idly on the deck, looking through rather than at, the deep blue sky " ; and occurs in the description of the journey from Harrisburg to Pittsburg by canal barge.

P. 245, l. 19. *Claude :* 1600–1682. The famous French landscape-painter. His skies are aerial and full of lustre, with every object harmoniously illumined.

l. 25. *Turner :* 1775–1851. The famous English landscape painter. Ruskin aided considerably in the proper appreciation of Turner's work.

P. 248, l. 31. *Cirrus :* wisps of cloud.

l. 32. *Stratus :* cloud formations of the appearance of a broad sheet of uniform thickness.

P. 250, ll. 30–31. *Burke on* " *Sublime* " *:* " A Philosophical Enquiry into the Origin of our Ideas of the Sublime and Beautiful," written by the famous orator, writer, and politician, Edmund Burke, in 1756. The passage to which Ruskin refers is as follows :—

" Another source of the sublime is Infinity ; if it does not rather belong to the last. Infinity has a tendency

to fill the mind with that sort of delightful horrour, which is the most genuine effect and truest test of the sublime. There are scarce any things which can become the objects of our senses, that are really and in their own nature infinite. But the eye not being able to perceive the bounds of many things, they seem to be infinite, and they produce the same effects as if they were really so. We are deceived in the like manner, if the parts of some large object are so continued to any indefinite number, that the imagination meets no check which may hinder its extending them at pleasure.

"Whenever we repeat any idea frequently, the mind, by a sort of mechanism, repeats it long after the first cause has ceased to operate. After whirling about, when we sit down, the objects about us still seem to whirl. After a long succession of noises, as the fall of waters, or the beating of forge-hammers, the hammers beat and the water roars in the imagination long after the first sounds have ceased to affect it ; and they die away at last by gradations which are scarcely perceptible. If you hold up a straight pole, with your eye to one end, it will seem extended to a length almost incredible. Place a number of uniform and equidistant marks on this pole, they will cause the same deception, and seem multiplied without end. The senses, strongly affected in some one manner, cannot quickly change their tenour, or adapt themselves to other things ; but they continue in their old channel until the strength of the first mover decays. This is the reason of an appearance very frequent in madmen ; that they remain whole days and nights, sometimes whole years, in the constant repetition of some remark, some complaint, or song ; which having struck powerfully on their disordered imagination in the beginning of their phrensy, every repetition reinforces it with new strength ; and the hurry of their spirits, unrestrained by the curb of reason, continues it to the end of their lives."

P. 253, l. 6. *Cuyp :* Albert Cuyp (1620–1691), the famous Dutch landscape painter. "He shows great cleverness in throwing pale-yellow clouds against clear blue skies. . . . He is also very artful in varying light and shade according to distance, either by interchange of cloud-shadow and sun-gleam or by gradation of tints."—"Encyclopaedia Britannica."

Dulwich Gallery: in the College and separately endowed in 1811. Famous for its collection of Dutch paintings.

P. 254, l. 5. *Salvator:* Salvator Rosa (1615–1673), the famous Italian painter of landscapes and battle-pieces.

Poussin: Nicolas Poussin (1594–1665), a famous French painter.

P. 256, l. 22. *Curvilinear:* contained by curved lines.

P. 260, l. 36. *Gaspars:* Jan Baptist Gaspars (1620–1691), the Dutch painter.

The Time Machine. From the novel of that name by H. G. Wells.

H. G. Wells (1866) began his career by taking a First Class Honours Degree in Science at London University. After a brief experience of teaching he turned to journalism and ultimately devoted himself almost entirely to scientific subjects. "The Time Machine" (1895) was the first of a long line of romances and novels in which from scientific data he works forward romantically towards the unknown and the future. Science, however, to Mr. Wells, is only useful as a guiding star to modern social and political development, and it is this aspect of the value of scientific discovery which is increasingly stressed in his more recent writings.

P. 270, l. 37. *Burslem:* one of the "Five Towns" immortalised by Arnold Bennett and now included in the city of Stoke-on-Trent.

EXERCISES

The Chemical History of a Candle.

1. Write an essay on a history of the use of and the methods of manufacturing candles.
2. Study R. L. Stevenson's essay "A Plea for Gas Lamps" in "Virginibus Puerisque," and summarise its main ideas.
3. Make a list of everyday incidents illustrating the theory of "capillary attraction."
4. "The perfection of a process—that is, its utility—is the better part of beauty about it." Discuss and illustrate this.

Soda-Water.

1. Make a list of so-called "conjurer's tricks" which admit of a scientific explanation.
2. Write an explanation of any modern application of a well-known scientific law or principle.

A Piece of Chalk.

1. Draw a geological sketch-map of the British Isles, marking the principal chalk deposits.
2. Make a list of what you consider are Nature's most wonderful metamorphoses.
3. Summarise the essential matter of this chapter under six or seven brief headings.

Old Red Sandstone.

1. On the map referred to in (1) above, mark the old red sandstone.
2. Write an essay on "Contentment."

Coral Formations.

1. Write an essay on "The Growth and Formation of Coral Reefs."

2. After a ramble or excursion into the country write up the flora and fauna in ordered sequence.

Martins and Swallows.

Write a detailed account of some species of bird, other than the swallow and the martin, which you have observed for yourself.

Gossamer.

This is a perfect little prose idyll. Try to write a similarly convincing essay on " Mushrooms " or " Hoar Frost."

Crickets.

1. " Thus the shrilling of the field-cricket, though sharp and stridulous, yet marvellously delights some hearers, filling their minds with a train of summer ideas. . . ." Write an essay on the theory of recollection and the association of ideas. See the note on page 290.

2. " And thus the humane inquirer may gratify his curiosity without injuring the object of it." Write an essay on " Hunter and Naturalist."

3. " They are the housewife's barometer." Make a list of similar " rural " barometers.

The Pageant of Summer.

" The poetry of earth is never dead," Keats. Write an essay with this as title.

Mind under Water.

What evidence of real intelligence have you discovered in birds, beasts, and animals ? Try to distinguish between real intelligence and mere intellect. How far do you agree with all that Jefferies claims for the fish in this extract ?

Observations on the Eel.

1. Make a list of some other series of observations of natural phenomena which have not yet been completed by the scientist.

2. Write an essay on " Science and Industry."

The Alligators of Guiana.

" Among the natives generally they are feared and

avoided, and are (mistakenly) accredited with great longevity, of one or two hundred years." Make a list of (*a*) exploded but once popular myths concerning Nature, (*b*) myths commonly believed to-day but which you yourself know to be fictitious.

Spinning-Tops and *Boomerangs*.

1. Express briefly each law of mechanics illustrated by the experiments described in these chapters.

2. (*a*) Devise six "magic tricks" each illustrating some law of chemical change. (*b*) State briefly the law of chemistry which each of your "magic tricks" illustrates.

A Scientist's Hut in the Antarctic.

1. Write an essay on "Pioneers of Research and Discovery."

2. Write an essay on "Necessity the mother of Invention."

Research in a Tropical Jungle.

"To settle down in a strange country and to study successfully the wild creatures which inhabit it demands a few of the elements of real warfare, combined, however, with a large percentage of luck, the chances of a gamble." Taking this as your text, write an essay on modern outlets for the spirit of adventure.

The Study of Astronomy.

1. Write an essay on "The Myths and Legends of Primitive Man."

2. Make a précis (about 500 words) of this extract as far as the middle of page 204.

3. "The author of this most excellent book is a man of science who is also an artist." Discuss the justice of this comment on Sir James Jeans.

Man's Place in the Universe.

1. This and the previous selection are on kindred subjects. Explain what these two writers have in common and in which ways they differ.

2. Write a short story based on some of the matter suggested in this extract.

3. Write an essay on "The Prodigality of Nature."

Relativity.

Select any particularly striking paragraphs in this extract and summarise the argument in your own words.

Cloud Forms and Painting.

Organise a debate on the proposition that townsmen appreciate rural beauty more fully than countrymen, or write one of the speeches for or against this subject and prepare the notes for a reply to the speech written.

The Time Machine.

1. Write an essay on "The Ultra-Modern."

2. "Our ancestors had no great tolerance for anachronisms." Discuss and illustrate.

3. Point out which parts of the story you consider are rightly founded on scientific fact and which parts you consider are merely imaginative.

4. What are the "reasonable risks in life a man has got to take"?

The following general exercises are best attempted only after the book as a whole has been studied :—

1. "Naturalists are prone to become moralists." Instance examples of this from the book and discuss the subject.

2. "Let men stew in their cities if they will. It is in the lonely places, in jungles and mountains, in snows and fires, in the still observatories and the silent laboratories, in those secret and dangerous places where life probes into life, it is there that the masters of the world, the lords of the beast, the rebel sons of Fate come to their own."—H. G. Wells. Discuss.

3. Write an essay on "Science and Fiction."

4. Flower in the crannied wall,
I pluck you out of the crannies ;
Hold you here, root and all, in my hand,
Little flower—but if I could understand
What you are, root and all, and all in all,
I should know what God and man is.

Tennyson.

Discuss this view of science.

5. Make a list of chance discoveries of scientific importance of which you have heard.

6. Describe in detail some scientific experiment which you yourself have conducted.

7. Explain as clearly as you can how one of the following functions : an electric bell, a petrol engine, an aeroplane, yeast.

8. Write a short biography of any great scientist.

9. Describe any manufacturing process which you have observed.

10. Describe the geographical formation of the country within a radius of 10 miles from your home.

11. Say where the following occur and explain their meaning :—

“ Man alone, more senseless than a pigeon, put a god in vapour.”

“. . . night followed day like the flapping of a black wing.”

“ The cataclysm was not confined to the realms of abstract thought, henceforth human existence itself was to appear in a new light, and human aims and aspirations would be judged from a different standpoint.”

“. . . a very exquisite pleasure may be a very cheap one, and . . . the busiest employments may afford leisure to enjoy it.”

“ It was between the May and the June roses.”

“ God is not in the earthquake, nor in the fire, but in the still small voice.”

“ It is not the best looking thing, but the best acting thing, which is the most advantageous to us.”

“ Behold the throne
Of Chaos and his dark Pavilion spread
Wide on the wasteful deep.”

“ By being the constant companions of her solitary hours they naturally become the objects of her superstition.”

12. Twinkle, twinkle, little star,
I don’t wonder what you are ;
You’re the cooling down of gases
Forming into solid masses.

Discuss this satirical view of the results of studying the “ Wonders of Science.”

Printed in Great Britain by R. & R. Clark, Limited, *Edinburgh.*